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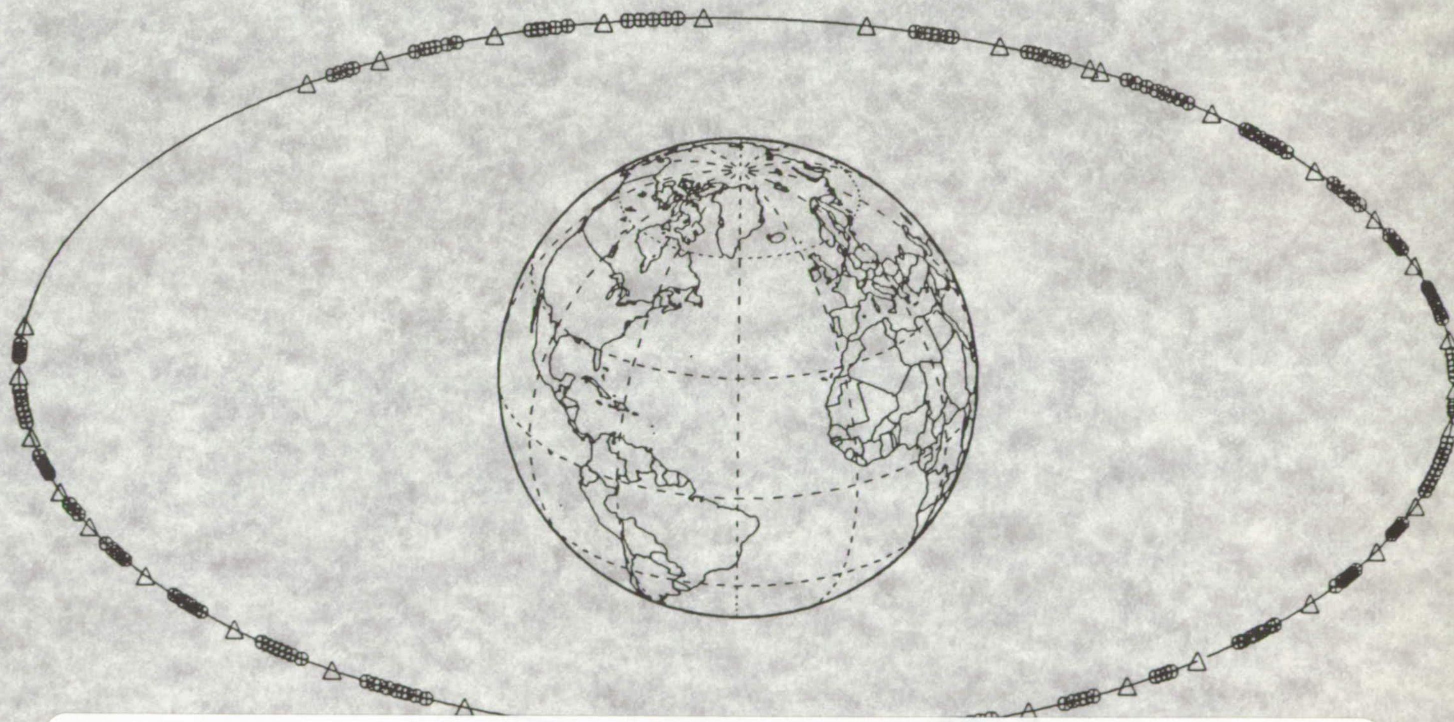
Numerical Arc Segmentation Algorithm for a Radio Conference – NASARC (Version 2.0)

User's Manual

Wayne A. Whyte, Jr., Ann O. Heyward, Denise S. Ponchak,
Rodney L. Spence, and John E. Zuzek



National Aeronautics and Space Administration
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PREFACE

The information contained in the *NASARC (Version* 2.0) *Technical Manual* (NASA TM-100160) and *NASARC (Version* 2.0) *User's Manual* (NASA TM-100161) relates to the state of NASARC software development through October 16, 1987. The technical manual describes the Numerical Arc Segmentation Algorithm for a Radio Conference (NASARC) concept and the algorithms which are used to implement the concept. The *User's Manual* provides information on computer system considerations, installation instructions, description of input files, and program operation instructions. Significant revisions have been incorporated in the Version 2.0 software over prior versions. These revisions have enhanced the modeling capabilities of the NASARC procedure while greatly reducing the computer run time and memory requirements. Array dimensions within the software have been structured to fit within the currently available 6-megabyte memory capacity of the International Frequency Registration Board (IFRB) computer facility. A piecewise approach to predetermined arc generation in NASARC (Version 2.0) allows worldwide scenarios to be accommodated within these memory constraints while at the same time effecting an overall reduction in computer run time.

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1.0 INTRODUCTION

This volume contains information on the installation and operation of the NASARC (Version 2.0) software package for the generation of predetermined arcs to aid in allotment planning procedures.

The first major section of this manual presents detailed instructions for the installation of the NASARC (Version 2.0) software package. While the specifics of the installation process may vary from site to site due to differences in computer hardware and operating systems, a sufficiently detailed procedure is provided to allow for straightforward installation.

The second major portion of this manual provides full information on the use of the NASARC package for planning exercises, including descriptions of all required input files and their preparation, directions for execution of the NASARC (Version 2.0) package, and guidelines for user-supplied technical parameter values. Information is also given on the use of the NASARC (Version 2.0) package in conjunction with the synthesis package ORBIT-II, which was developed by the Kokusai Denshin Denshin Denwa Co, Ltd., Tokyo, Japan.

Detailed information on the concepts and algorithms contained in the NASARC (Version 2.0) software package may be found in the *NASARC (Version* 2.0) *Technical Manual* (NASA TM-100160).

2.0 INSTALLATION OF THE NASARC SOFTWARE PACKAGE

In this section, full instructions are given for the installation of the NASARC software package. Information is given on the attributes of the magnetic tape that contains the NASARC package, creation of program modules from source codes, construction of appropriate commands necessary to utilize the NASARC software, and attributes of files needed for program input and output. Prior to this detailed information, a discussion of system considerations for NASARC installation is given to aid the user in determining appropriate installation procedures for his specific machine and operating system.

2.1 System Considerations for NASARC Installation

In the following sections, information is given on the language and storage requirements of the NASARC software package.

2.1.1 Language/Compiler Requirements

The NASARC software package is written in the (ANSI standard) FORTRAN 77 computer language. An effort has been made to ensure that no extensions of the language that are specific to a particular system or machine have been introduced into the software package. Thus, the user should be able to compile the appropriate NASARC source codes using an (ANSI standard) FORTRAN 77 compiler suitable for the user's system.

2.1.2 Storage and Memory Requirements

To aid the user in successfully installing and running the NASARC software package on his system, both file storage requirements and run-time memory requirements are now given. The user should note that these requirements concern the NASARC source code files and program modules only; storage requirements for associated input and output files are discussed in section 2.3.

Source file storage requirements:

NASARC0 source code:	62.24 kilobytes
NASARC1 source code:	209.12 kilobytes
NASARC2 source code:	374.56 kilobytes
NASARC3 source code:	192.32 kilobytes

Object code storage requirements:

NASARC0 object code:	0.034250 megabyte
NASARC1 object code:	1.040864 megabytes
NASARC2 object code:	0.283970 megabyte
NASARC3 object code:	0.856938 megabyte

Run-time memory requirements:

NASARC0 module:	0.282536 megabyte
NASARC1 module:	5.560208 megabytes
NASARC2 module:	5.921922 megabytes
NASARC3 module:	1.101836 megabytes

2.1.3 Tailoring NASARC to the Operating System

The NASARC software package was developed on an Amdahl 5860 running under the IBM VM operating system. While example job control language is included in this manual, the user should note that commands needed to load and run the NASARC modules and create and define files will depend on the user's operating system. All such system commands are external to the NASARC programs; therefore, no modification to the NASARC source code is necessary to adapt the package to any particular operating system.

2.2 Detailed Installation Instructions for the NASARC Software Package

In this section, detailed instructions are given for the installation of the NASARC software package. As was mentioned in section 2.1.3, the specific procedure used to install the NASARC package will differ for different operating systems. However, the guidelines presented in the following sections are sufficiently detailed to allow straightforward installation of the NASARC package.

2.2.1 Magnetic Tape Attributes

The NASARC software package is provided on a magnetic tape with the following attributes:

Number of tracks, 9	Number of files, 19
Density, 6250 bpi	Logical record length, 80 bytes
Character set, EBCDIC	Block size, 800

All files included on the tape should be unloaded; source code files should then be compiled to create the appropriate program modules. The files included, and their attributes and purposes, are listed in table 2.2-l in the order in which they appear on the tape. The user is referred to sections 2.1.2 and 2.3 for information on file storage requirements.

TABLE 2.2-1—FILES INCLUDED ON MAGNETIC TAPE

File name	Purpose	Record length	Block size
NASARC0	Fortran source code	80	800
NASARC1	Fortran source code		
NASARC2	Fortran source code		
NASARC3	Fortran source code		
EXEC	NASARC procedure (VM system)		
POINTS	Point Sets file		
BEAMS	Ellipse file		
ARC55	Service Area file for 55-satellite scenario		
DATA55	Input Data file for 55-satellite scenario		
SEG1	Segments file for use with ARC55, AFF55 scenarios		
RPT55	NASARC Report file produced by ARC55 scenario	132	1320
AFF55	Service Area file for 55-satellite scenario, with affiliated service areas	80	800
CODE55	Affiliated Sets file for AFF55 scenario	80	800
DAFF55	Input Data file for use with 55-satellite scenario AFF55	80	800
RPTAFF	NASARC Report file produced by AFF55 scenario	132	1320
WRLD10	Service Area file for world scenario	80	800
DATAWD	Input Data file for WRLD10 scenario	80	800
SEG9	Segments file for use with WRLD10 scenario	80	800
RPTWLD	NASARC Report file, produced with WRLD10 scenario	132	1320

2.2.2 Creation of NASARC Program Modules

After the files included on the magnetic tape have been unloaded and named according to the conventions of the user's system, four compiled modules must be created from the four source files (NASARC0, NASARC1, NASARC2, and NASARC3) included on the tape. While conventions for naming load modules will differ from system to system, the modules should be named to correspond as closely as possible to the designations NASARC0, NASARC1, NASARC2, and NASARC3 as this will aid the user in following the directions in the remainder of this manual.

Each module has a specific purpose within the software package as a whole. NASRC0 is the input program, which prompts the user for input parameter values and verifies as correct all inputs supplied via input files; an additional input file is created from interactively supplied user inputs, which will be utilized by NASARC1, NASARC2, and NASARC3. These three modules are used iteratively in a piecewise approach to the orbital arc defined by the user. NASARC1 is the grouping program, which enumerates a list of compatible groupings of administration and the arc segments over which each such grouping may exist. NASARC2 is the arc determination program, which accepts the output of NASARC1 as input and selects appropriate groupings, determines their allotted arc lengths, and arranges the arc segments in orbit. NASARC3 is the group arc extension program, which examines compatible groups of administrations selected by NASARC2 in order to determine possible extensions of their potential predetermined arcs, should rearrangement of arcs in orbit become necessary in examination of subsequent pieces of the orbital arc.

A more detailed explanation of the purposes of NASARC0, NASARC1, NASARC2, and NASARC3 may be found in the *NASARC Technical Manual*; storage and memory requirements for each program module are addressed in section 2.1.2 of this manual.

Tables 2.2-2, 2.2-3, 2.2-4, and 2.2-5 contain complete listings of the names of the programs and subroutines that should appear in each program module after compilation. The purpose of each subroutine is also briefly described. For further insight on the structure of the NASARC modules, the user is referred to the flow charts presented in section 3.1.

TABLE 2.2-2—PROGRAMS AND SUBROUTINES IN NASARC0
MODULE AFTER COMPILATION

Program/subprogram name	Purpose of program/subprogram
MAIN	Prompt user for interactive inputs; assemble interactive inputs into input data file utilized by NASARC1, NASARC2, NASARC3. Verify all externally created input files consistent and correct.
INTRST	Determine intersection endpoints of pair of arc segments; used to verify that arcs of affiliated service arcs intersect.

TABLE 2.2-3—PROGRAMS AND SUBROUTINES CONTAINED IN NASARC1 MODULE AFTER COMPILATION

Program/subprogram name	Purpose of program/subprogram
MAIN	Determine compatible groupings and arc segments over which they may exist, in current portion of orbit.
SETCON	Set constants used throughout programs.
INTRST	Determine intersection endpoints of pair of arc segments.
POSPAR	Position Point Sets file to desired block of data.
RDPTST	Read sets of polygon points for service areas from Point Sets file.
ERR	Change initial error flag of Input Data file to Y if error encountered.
CREATE	Read necessary ellipses from master Ellipse file and store in array.
CICHK	Verify that grouping criterion provides sufficient orbital separation to achieve target C/I value.
SCOFF	Calculate spacecraft antenna off-axis angle.
ESOFF	Calculate earth station off-axis angle.
BW	Calculate half-power beamwidth for interfering satellite antenna in direction of wanted service area polygon point.
ARTAN	Trigonometric calculation for BW subroutine.
DISC	Calculate antenna discrimination.
ACCUM	Accumulate individual groupings, locations into list of groupings and segments.
ARCSEG	Form list of compatible groups, individual locations into list of groups, arc segments.
QUICK1	Sort list in ascending order on two fields. Primary field is compatible group string; secondary field is arc location at which group occurs.
PART1	Partition list of elements to be sorted.
QUICK2	Sort list of compatible groups, arc segments in ascending order, by compatible group and western group arc boundary.
PART2	Partition list of elements to be sorted.
CHK180	Determine if group arc span crosses 180° east longitude. (Entry within subroutine ACCUM.)
OUTLST	Output service areas, service arc longitudes, individual buffer lengths, list of groupings, arc segments.

TABLE 2.2-4—PROGRAMS AND SUBROUTINES CONTAINED IN NASARC2 MODULE AFTER COMPILATION

Program/subprogram name	Purpose of program/subprogram
MAIN	Select appropriate groups from NASARC1 output; determine allotted arc lengths in order to place all administrations into geostationary orbital arc.
INPARM	Read NASARC input parameters (C/I, downlink frequency, antenna diameters, etc.) from Input Data file.
INSEGS	Read Intermediate Segments file; determine bounds of cumulative arc, bounds of current segment, and direction of allotment buildup (E-W or W-E).
INGRPS	Read service arc information relevant to present portion of orbit (service areas, service arc longitudes, buffer arcs), along with groups, group arcs generated over present portion of orbit from current Groups file.
LSTPAR	Echo NASARC input parameters in Intermediate Selection file.
INALLT	Read groups, allotted arc bounds, group arc bounds selected in prior portions of orbit, from Intermediate Allotted Groups file.
INRMN	Read those groups that adjoin either edge of current portion of arc, from Unallotted Groups file.
JOINER	Append unallotted groups list read by INRMN to group list generated by NASARC1 for current portion of orbit; join group arcs of duplicate groups where overlapping or contiguous.
PARTIT	Partition current service areas into 3 priority classes according to service arc remaining outside cumulative arc.
CRTADM	Determine information for each service area from master group list, to find critical service area, including number of service areas remaining in groups list, remaining service areas, and frequency of occurrence of each service area. Return service area appearing in fewest number of groups, having smallest service arc, as critical service area.
MISSP1	Check if Priority 1 service areas are missing from master groups list.
TEMPOR	Find temporary allotted arc for critical group within group arc, changing previous temporary allotted arcs if necessary.
LSTALT	Write current allotted arcs to Intermediate Selection file, and to Intermediate Allotted Groups file, at end of execution for present portion of orbit.
CRTGRP	Determine critical group containing critical service area from master groups list. Critical group is that with largest number of service areas, largest group arc length, smallest total frequency of occurrence.
P1CHK	Logical function subprogram; check if service area is Priority 1 service area. Return true if P1, false otherwise.

TABLE 2.2-4—Continued.

Program/subprogram name	Purpose of program/subprogram
SEGCHK	Check if remaining arc in current portion of orbit is sufficient to allot at least a 2 member group of Priority 2 or Priority 3 service areas. If not, no more arc allotments will be found and NASARC2 will stop.
OUTRMN	Scan remaining groups in master list (after arc determination process for present portion of orbit is completed); identify groups whose group arc adjoins one edge of the cumulative arc. Write groups to Unallotted Groups file.
UPDATE	Update master groups list after arc allotted, by deleting allotted critical group members from groups in list, joining group arcs of resultant duplicate groups where overlapping or contiguous, and eliminating duplicates where appropriate.
UNPACK	Convert group from packed format (no spaces between service area codes) to unpacked format (space separating service area codes in group) to improve readability when writing groups to files.
ITUARC	Import service area; export associated visible service arc longitudes, arc length.
GRPBUF	Determine group buffer by examining service area buffers of member service areas, selecting largest.
DENSE	Determine whether arbitrary portion of arc is occupied by prior temporary allotted arcs.
PTACHK	Find prior temporary allotted arcs lying within, overlapping desired potential temporary allotted arc. For each of these, determine if contiguous arc space is available within group arc to move allotted arc to location allowing desired arc to be allotted.
SUBBOA	Subtract group's temporary allotted arc from orbital arc.
ADDBOA	Add group's temporary allotted arc to orbital arc.
PUSH	Allots arc by moving prior allotted arcs. Relative ordering of allotted arcs to east or west of current location will not change.
SHUFFL	Allots arc by moving and permuting prior allotted arcs. Relative ordering of allotted arcs may change.
ARCCHK	Identify prior allotted arcs intersecting specified portion of orbital arc.
XTRACT	Extract critical group members from given group in master list.
PULL	Places individual service areas from group into separate elements of array.
INDEX2	Find starting column of 3-character service area code within group character string.
CHK180	Logical function subprogram; determines if given arc span straddles 180° meridian.
ADJST1	Adjust two longitudes defining arc boundaries so that westernmost edge is numerically less than easternmost edge; both in range 0° to 360°.
EXTEND	Extend group arcs of groups which are subsets of other groups, when forming critical groups sublist.

TABLE 2.2-4—Concluded.

Program/subprogram name	Purpose of program/subprogram
COMBIN	Used in subset arc extension, when forming critical groups sublist.
QUICK1	Used in groups list updating process; employs Quicksort algorithm (devised by C.A.R. Hoare). Sort groups list alphabetically; for same group, order group arcs west to east. For duplicate groups with same west longitude, places group arc extending furthest east first.
PART1	Partitioning module, used by QUICK1.
QUICK2	Used in forming the critical groups sublist; employs Quicksort algorithm. Perform compound sort on sublist; first, on number of members in group (descending order); then on group arc length (descending order); then group's total frequency of occurrence (ascending order).
PART2	Partitioning module, used by QUICK2.
QUICK3	Quicksort routine used in subset arc extension process, when forming critical groups sublist. Performs compound sort on sublist; first, on number of members in group (ascending order); then alphabetically (ascending order); then on western longitude of group arc (ascending order).
PART3	Partitioning module, used by QUICK3.
QUICK4	Quicksort routine used in subset arc extension process. Sorts group arcs in west to east order; for segments with same west longitude, places segment that extends furthest east first.
PART4	Partitioning module, used by QUICK4.
QUICK5	Quicksort routine used in formation of critical administration list. Sorts administrations in ascending order, first on frequency of occurrence of service area in master groups list, then on visible service arc length.
PART5	Partitioning module, used by QUICK5.
PTRBUB	Pointer bubble sort routine; sorts potential temporary allotted arcs in TEMPOR according to number of intersections that each has with prior temporary allotted arcs.

TABLE 2.2-5—PROGRAMS AND SUBROUTINES CONTAINED IN NASARC3 MODULE AFTER COMPILATION

Program/subprogram name	Purpose of program/subprogram
MAIN	Extend group arcs of cumulative set of groups given allotted arcs by NASARC2 module, if possible, within current portion of orbit.
SETCON	Set constants used throughout programs.
INTRST	Determine intersection endpoints of pair of arc segments.
POSPAR	Position Point Sets file to desired block of data.
RDPTST	Read sets of polygon points for service areas from Point Sets file.
ERR	Change initial error flag of Input Data file to Y if error encountered.
CICHK	Verify that grouping criterion provides sufficient orbital separation to achieve target *C/I* value.
SCOFF	Calculate spacecraft antenna off-axis angle.
BW	Calculate half-power beamwidth for interfering satellite antenna in direction of wanted service area polygon point.
ARTAN	Trigonometric calculation for BW subroutine.
DISC	Calculate antenna discrimination.
REPORT	Produce output report of NASARC results, when all portions of orbit within Segments file are exhausted.
UNPACK	Convert group from packed format (no spaces between service area codes) to unpacked format (space seperating service area codes in group) to improve readability when writing groups to files.

2.2.3 Creation of Commands/Job Control Language Necessary to RUN NASARC Programs—NASARC Procedure

It was stated earlier that the specific set of system commands and/or job control language statements needed to exercise the NASARC package program modules would differ for different operating systems. Thus, the user must issue the commands and/or job control language statements that are suitable for the system in use. While the specific commands issued by the user will depend on the user's system, the general list of functions that must be performed by such commands is consistent for all systems. Many operating systems allow the user to create a single named procedure that executes a sequence of system commands; it is suggested that such a procedure be created to perform the following described operations.

To utilize the NASARC software package for allotment planning purposes, all four of the NASARC modules (NASARC0, NASARC1, NASARC2, NASARC3) must be executed in the proper sequence. If multiple segments are being run, NASARC1, NASARC2, and NASARC3 must be consecutively executed in a repeated fashion for all segments specified by the user. (See fig. 2.2-1.)

The NASARC0 module is the first program element that must be executed, and it is executed only once. Its purpose is to create the Input Data file from user prompted inputs for the remaining NASARC modules to use when executing. It reads from the Service Area file, Point Sets file, Affiliated Sets file, and Segments file. It prompts the user for the input parameters (*C/I*, frequency, grouping criterion, minimum HPBW, E/S code, E/S diameter, E/S antenna efficiency, S/C code, S/C parameter, and S/C antenna efficiency) and checks if they are within established limits. Also, an error checking procedure is performed to determine if all files are structured correctly. When an error is discovered, an error flag is set to Y (yes). This flag is read by all subsequent

The NASARC EXEC Procedure

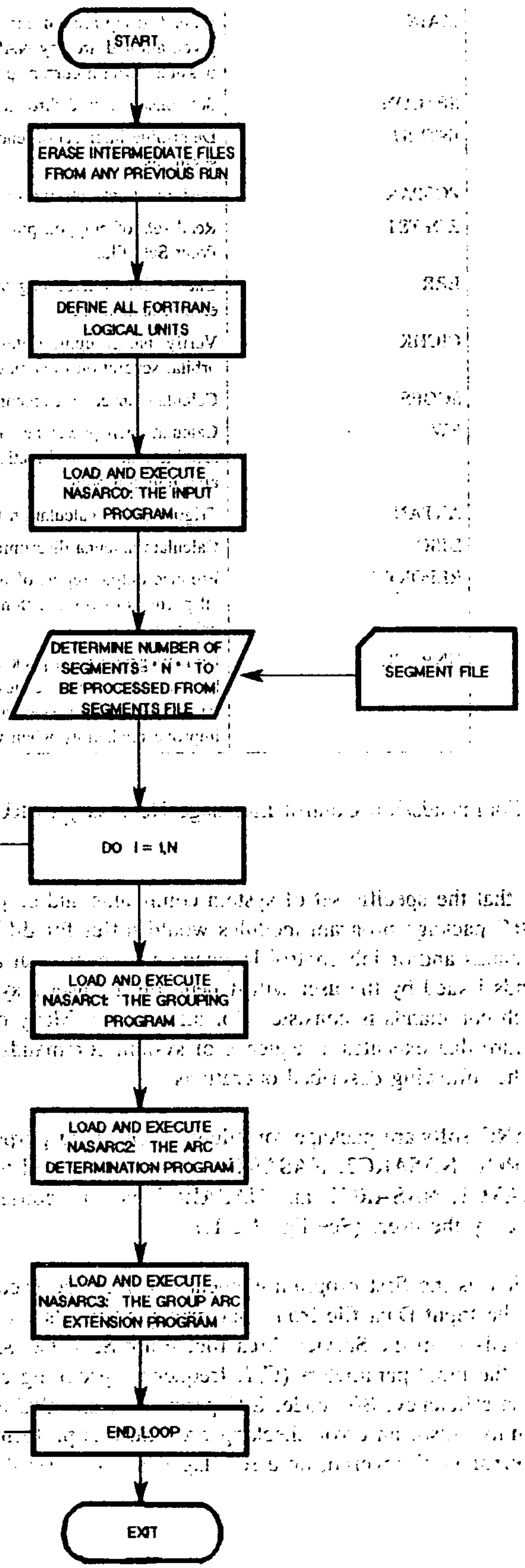

Figure 2.2-1.

program elements through the Input Data file and if it is set to Y, it causes them to immediately STOP executing—thus preventing unnecessary erroneous runs.

The NASARC1 program reads all of the files read by the NASARC0 program and, in addition, the Input Data file, the master Ellipse file, and the Intermediate Allotted Groupings file. NASARC1 produces two files that are used by NASARC2—the Groups file and the Intermediate Segments file. Also, the Segments file is modified for subsequent runs of the NASARC1 module.

The NASARC2 program reads from the Input Data file, the Intermediate Allotted Groupings file, the Unallotted Groups file, and the two files created by NASARC1. Its updated result, after each segment is executed, is stored in the Intermediate Allotted Groups file. NASARC2 also generates an Intermediate Selection file which provides information on the selection of the allotted groups.

The NASARC3 program serves two purposes. Before the last segment is executed it performs the group arc extension function. For this, it reads the Service Area file, master Ellipse file, Point Sets file, Affiliated Sets file, Input Data file, Intermediate Segments file, and Intermediate Allotted Groupings file. After execution, its results are stored in a modified Intermediate Allotted Groupings file. When executing the last segment, NASARC3 restores the original Segments file and produces the NASARC output document contained in the NASARC Report file.

To perform the tasks described, the NASARC procedure should contain appropriate system commands and/or job control language to execute the following sequence of instructions in the following order presented (see also fig. 2.2-1):

(1) For BATCH processing only, set and define necessary job parameters.

(2) Erase intermediate files from any previous run:

- (a) Erase Intermediate Allotted Groupings file.
- (b) Erase Intermediate Segments file.
- (c) Erase Unallotted Groups file.
- (d) Erase Groups file.
- (e) Erase Error Message file.
- (f) Erase Intermediate Selection file.

(3) Define all FORTRAN logical units:

- (a) Define FORTRAN logical unit 10 as the terminal (output unit for interactive queries to user).
- (b) Define FORTRAN logical unit 11 as the terminal (input unit for interactive queries to user).
- (c) Define FORTRAN logical unit 12 as the Input Data file, with appropriate file attributes.
- (d) Define FORTRAN logical unit 13 as the Service Area file, with appropriate file attributes.
- (e) Define FORTRAN logical unit 14 as the Affiliated Sets file, with appropriate file attributes.
- (f) Define FORTRAN logical unit 15 as the Point Sets file, with appropriate file attributes.
- (g) Define FORTRAN logical unit 16 as the Segments file, with appropriate file attributes.
- (h) Define FORTRAN logical unit 17 as the Intermediate Segments file, with appropriate file attributes.
- (i) Define FORTRAN logical unit 18 as the Ellipse file, with appropriate file attributes.
- (j) Define FORTRAN logical unit 19 as the Error Message file, with appropriate file attributes.
- (k) Define FORTRAN logical unit 20 as the Groups file, with appropriate file attributes.
- (l) Define FORTRAN logical unit 21 as the Intermediate Allotted Groupings file, with appropriate file attributes.
- (m) Define FORTRAN logical unit 22 as the Unallotted Groups file, with appropriate file attributes.
- (n) Define FORTRAN logical unit 23 as the Intermediate Selection file, with appropriate file attributes.
- (o) Define FORTRAN logical unit 24 as the NASARC Report file, with appropriate file attributes.

(4) Load and execute the NASARC0 module.

(5) Determine the number of segments to be run (N).

(6) Load and execute the NASARC1 module.
(7) Load and execute the NASARC2 module. } Loop through instructions (6), (7), and (8), N times.
(8) Load and execute the NASARC3 module.
(9) For BATCH processing only, submit job for processing.

If the user's system is unable to perform the loop indicated previously, it would be necessary to repeat steps (6) to (8) as many times as there are segments to be run.

2.3 Auxiliary File Requirements

The NASARC software package requires several auxiliary files for program input and output. Auxiliary files needed fall into one of three categories: input files, which are generally prepared prior to execution of the NASARC modules; intermediate files, which are generated by NASARC programs for temporary use; and output files, which are produced at the end of use of the NASARC package. The contents, formats, and approximate storage requirements (where possible) of each file are described in the following sections.

2.3.1 Input Files

In general, input files are those required for use by one or more of the NASARC0, NASARC1, NASARC2, or NASARC3 modules. With one exception (discussed in section 2.3.1.5), these files are generated externally to the NASARC modules. Two such files (discussed in sections 2.3.1.3 and 2.3.1.6) are furnished with the NASARC software package and should require little or no user modification. The remaining files must, when constructed by the user, adhere to the file structure, format, and content described in the appropriate section.

2.3.1.1 Segments File

The NASARC (Version 2.0) software package is based on an approach to the development of predetermined orbital arcs that differs in a significant respect from the approach utilized in prior versions of the software. NASARC (Version 2.0) applies the general concepts and calculations utilized by earlier versions of the software in a piecewise approach to the orbital arc as a whole; that is, a segment of the orbital arc is examined for compatible groups of service areas, and the arc spans over which such groups may exist are found. These group arcs will lie within the portion of the arc currently being examined. From the list of groups and group arcs, selections of groups will be made and predetermined arcs will be found for the selected groups. These arcs will also lie in the portion of the arc currently being examined. The process will be repeated for subsequent segments of the arc.

The segment file contains the portions of arc that are to be sequentially examined. Each segment is listed by its western and eastern limiting longitude; each record of the file contains one segment. Up to 40 such records may be included in the file; the records may span the entire 360° of available orbital arc, which is regarded by NASARC Version 2.0 as ranging from −179° east longitude to 180° east longitude. If a portion of the orbit under consideration crosses the 180° meridian, the western edge of the arc segment may have a positive longitude, while the eastern edge has a negative longitude.

The portions of orbital arc listed within the Segments file must be disjoint; that is, no two segments of the orbit that are listed in the file should encompass arc locations that overlap. Two portions of arc whose western and eastern boundaries (respectively) are separated by 1° of orbital arc are considered to be adjoining portions of the arc. After the first portion of the arc listed within the segment file, each subsequent segment must adjoin either the eastern or western arc boundary of one of the prior segments.

The specific format in which each record must be constructed is (1X, F7.2, 1X, F7.2), and can be illustrated as follows:

		±	X	X	X	.	X	X		±	X	X	X	.	X	X
Column no.:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Columns 2 through 8 of each record should contain the western boundary of each portion of the orbit to be considered, expressed in degrees east longitude in the range −179.00 to 180.00. Similarly, columns 10 through 16 should contain the eastern boundary of each segment to be considered in the range −179.00 to 180.00.

As each record in the file is of fixed, 80-byte length, and up to 40 such records may be included in the file, the segment file may occupy up to 3.2 kilobytes of memory.

2.3.1.2 Service Area File

The Service Area file is a particularly important file in several respects. First and foremost, this file is a complete listing of all service areas to be considered as candidates for an allotted arc. However, the file also contains information specific to each service area that influences outcomes and decision processes throughout each of the four NASARC program modules.

Each record of the Service Area file may contain up to eleven items. The first three items must be specified for each service area; the remaining items are optional. The first item of each record is a three-character service area code representing an administration or service area. These codes are generally taken from the country symbols appearing in the International Frequency List. This item must be followed, in each record, by the western and eastern longitudinal limits of the service area's service arc, corresponding to a given elevation angle. As for the Segments file (see section 2.3.1.1) longitudes range from −179° east longitude to 180° east longitude; if a service arc crosses the 180° meridian, its western service arc boundary will be positive while the eastern arc boundary is negative.

The remaining eight items of each record of the Service Area file are optional; specification of each optional item depends on the complexity of the situation the user wishes to examine with the NASARC software package. These optional items relate to the specification of affiliated sets of service areas, inclusion of inhomogeneity in the interference calculation, and specification of individual space station and earth station antenna characteristics.

The first optional item in each Service Area file record is an integer numeric code used to identify a single service area as a member of an affiliated set of service areas. Briefly, the concept of an affiliated set of service areas allows the user to consider situations in which several service areas are to be served from a single orbital location; for example, a nation with widely dispersed territories. By identifying each such service area with the same integer numeric code, the user signifies to the NASARC program modules that, in any compatible grouping found, either all or none of the member service areas must be included. The concept of an affiliated set of service areas is discussed in greater detail in the *NASARC* (*Version* 2.0) *Technical Manual.*

The second optional item in each Service Area file record is a real quantity—the inhomogeneity factor—expressed in decibels (dB). This quantity allows the user to take into account such inhomogeneities between service areas as rain attenuation and differing spacecraft power levels. If this optional value is not supplied, calculations will be performed on the basis of constant power flux density at the edge of the minimum area ellipse for all service areas. The inhomogeneity factor is described in greater detail in sections 3.1.1.2.3 and 3.2.2.5 of the *NASARC* (*Version* 2.0) *Technical Manual.* The user is strongly urged to refer to these sections, in order to fully understand the specification and use of the inhomogeneity factor, prior to exercising this option.

The third, fourth, and fifth optional items in each Service Area file record relate to the individual specification of space station antenna characteristics. The third optional item is a six-character code identifying a choice of space station transmit antenna patterns to be utilized for the particular service area in question. The user may select

such a pattern for each service area, if desired; if no pattern is specified, the pattern assumed will be that supplied interactively by the user to the NASARC0 program. For further information on the choice of patterns available, the user is referred to section 3.1.2.3 of the *NASARC* (*Version* 2.0) *Technical Manual* and to section 3.2.2.4 herein.

The fourth and fifth optional items in each Service Area file record also relate to space station antenna characteristics for the individual service area. These items are the space station antenna parameter value and the space station antenna efficiency. The space station antenna parameter value must be specified relative to the choice of the space station antenna pattern selected. The needed space station parameter value may represent different quantities such as a sidelobe level expressed in decibels, or an antenna decay constant expressed as a real number, depending on the choice of pattern selected. If no pattern choice is specified for the service area, the user may still use the antenna parameter option to assign a different parameter value to the service area than that specified by the user prompted default value. It must be recognized, however, that for this circumstance, the parameter value must correspond appropriately with the default antenna pattern choice. A value for the fifth option, antenna efficiency, may be specified independently of the pattern choice. It allows the user to specify a space station antenna efficiency that corresponds to the specific antenna choice and parameter value already specified in the record, or simply to vary the efficiency from the default (interactively supplied) value. The antenna efficiency is expressed as a decimal percentage (e.g., 55% = 0.55). A more detailed discussion of space station antenna parameters is presented in the *NASARC* (*Version* 2.0) *Technical Manual* and in section 3.2.2.4 herein.

The sixth, seventh, and eighth optional items provide similar options to those described previously for the space station transmit antenna; however, the sixth through eighth options relate to the earth station receive antenna. Further discussion of pattern choices, parameter values, and efficiencies is given in the *NASARC* (*Version* 2.0) *Technical Manual* and in section 3.2.2.5 herein.

The Service Area file must be constructed with service area codes in alphabetical order. This is done to maintain order compatibility with the Ellipse file (see section 3.2.6 herein). Such ordering must be performed by the user as the NASARC modules do not permute the order of the input records; the records are stored and processed in the order in which they are read. The specific format in which Service Area file records must be constructed is presented in table 2.3-1.

As each record in the file is of fixed 80-byte length and up to 300 such records may be included in the file, the Service Area file may occupy up to 24 kilobytes of memory.

TABLE 2.3-1—FORMAT OF SERVICE AREA FILE

Item	Column	Description	Format	Item	Column	Description	Format
1	2 to 4	Three-character service area code	A3	7	39 to 43	Spacecraft transit antenna parameter value	F5.2
2	6 to 12	Western service arc boundary, degrees east longitude	F7.2	8	45 to 48	Spacecraft antenna efficiency	F4.2
3	14 to 20	Eastern service arc boundary, degrees east longitude	F7.2	9	50 to 55	Earth station receive antenna pattern code	A6
4	22 to 23	Numeric code for set affiliation	I2	10	57 to 61	Earth station receive antenna diameter	F5.2
5	25 to 30	Inhomogeneity factor, dB	F6.2	11	63 to 66	Earth station receive antenna efficiency	F4.2
6	32 to 37	Spacecraft transmit antenna pattern code	A6				

2.3.1.3 Point Sets File

The Point Sets file is supplied on the magnetic tape containing the NASARC software package. The Points Sets file is utilized by the NASARC0, NASARC1, and NASARC3 modules and contains two different types of data. In this respect, the Point Sets file differs from the two input files discussed previously.

As its name suggests, the Point Sets file contains sets of polygon points defining boundaries of service areas. Prior to the occurrence of this data, however, a block of data exists that contains values for a series of four constants utilized in the calculation of the length of the allotted arcs to be given to service areas by the NASARC2 module. The different types of data are separated by special file separator characters—a series of 4 asterisks (****). The general structure of the Point Sets file is illustrated in figure 2.3-1.

The constants contained in the first block of data are accessed only once, within this file, by the NASARC0 module. The NASARC0 module appends the four constant values to a list of data inputs supplied interactively by the user in the construction of the Input Data file (see section 2.3.1.5). Further discussion of the precise usage of these values in the calculation of a predetermined arc length is contained in section 3.3.4 of the *NASARC (Version* 2.0) *Technical Manual.* The user is strongly urged to refer to this section before altering the constant values presently included in the Point Sets file.

The point set data contained in the Point Sets file include a set of polygon points, expressed as latitude-longitude pairs, for each of 222 service areas. Polygon points are those which define the boundaries of the service area or administration and are selected so as to form a convex polygon on the surface of the Earth. For NASARC (Version 2.0) up to 10 such points may be specified for each service area. The boundaries of a service area may

```
CONSTANTS FOR ALLOTED ARC EQUATION IN NASARC2 - C1,C2,C3,C4 (4(F10.0))
  1.0       1.0       0.0        0.0
****
****
POINT SETS FOR SERVICE AREAS
****
AFG01AFG      DN  6        AFGHANISTAN
AFG02    1P 37.20  74.80           2P 38.50  71.00           3P 37.50  65.60
AFG02    4P 35.40  61.20           5P 30.00  66.30           6P 29.90  61.00
AFS01AFS      DN  6        SOUTH AFRICA
AFS02    1P-22.00  29.50           2P-28.75  16.30           3P-34.90  20.00
AFS02    4P-24.80  20.00           5P-26.80  33.20           6P-33.80  27.00
AGL01AGL      DN  5        ANGOLA
AGL02    1P-17.50  12.00           2P -6.50  12.50           3P-11.00  24.00
AGL02    4P-17.50  23.00           5P -7.00  20.00
AIA01AIA      DN  3        ANGUILLA
AIA02    1P 18.32 -62.95           2P 18.20 -63.27           3P 18.10 -63.13
ALB01ALB      DN  6        ALBANIA
ALB02    1P 42.60  19.80           2P 41.80  19.30           3P 40.40  19.40
ALB02    4P 39.70  20.30           5P 40.90  21.00           6P 42.00  20.70

   .
   .
   .

ZAI01ZAI      DN  6        ZAIRE
ZAI02    1P  5.00  19.50           2P  3.80  31.00           3P -5.60  12.00
ZAI02    4P-11.10  22.10           5P-13.50  29.80           6P -8.20  30.70
ZMB01ZMB      DN  6        ZAMBIA
ZMB02    1P -8.00  28.50           2P -9.00  33.00           3P-13.80  33.00
ZMB02    4P-17.50  25.50           5P-16.60  22.00           6P-13.00  22.00
ZWE01ZWE      DN  6        ZIMBABWE
ZWE02    1P-17.70  25.20           2P-15.60  30.30           3P-16.50  32.80
ZWE02    4P-20.00  32.80           5P-22.60  31.50           6P-21.70  28.20
****
```

Figure 2.3-1—General data structure of Point Sets file.

be adequately represented by six or fewer such points; the Point Sets file included with the NASARC (Version 2.0) software package utilitizes six or fewer points per service area. The user will save a considerable amount of time in file editing and construction by employing the master Point Sets file that includes point set data for all administrations and service areas rather than constructing an individual Point Set file for each scenario. Polygon point sets may be added to the Points Sets file for new service areas, such as subregional coverages which may be identified. The data contained in the Point Sets file must conform to specific formats. These formats are described in tables 2.3-2 and 2.3-3.

The format for point set data is described in table 2.3-3. Each set of points corresponding to an individual service area will contain an initial descriptive record. Contained in this record are the three-character service area code, record type (=1 for the initial record), downlink flag (always = D), the number of polygon points for the service area and (optionally) a comment describing the set of points to follow. This initial descriptive record is followed by a series of records containing the polygon points themselves. The number of such records utilized for the service area depends on the total number of points specified in the initial record; up to three points are listed on each record following the initial record. Each of these records contains the three-character service area code, the record type (=2), and a series of three sets of columns, each set containing the point number (1, 2, 3, etc.), the point type (always P), and the point latitude and point longitude.

The Point Sets file occupies 50.56 kilobytes of memory as furnished with the NASARC (Version 2.0) software package.

TABLE 2.3-2—FORMAT FOR CONSTANT DATA CONTAINED IN POINT SETS FILE

Item	Column	Description	Format
1	1 to 10	Constant, C_1	F10.0
2	11 to 20	Constant, C_2	F10.0
3	21 to 30	Constant, C_3	F10.0
4	31 to 40	Constant, C_4	F10.0

TABLE 2.3-3—FORMAT FOR POINT SET DATA FOR INDIVIDUAL SERVICE AREA

Item	Column	Description	Format
		Initial record	
1	1 to 3	Three-character service area code	A3
2	5	Record type (=1)	I1
3	14	Up or downlink flag (=D)	A1
4	17 to 18	Number of points for service area	I2
5	19 to 80	Descriptive comment (optional)	A61
		Subsequent record	
1	1 to 3	Three-character service area code	A3
2	5	Record type (=2)	I1
3	6 to 9	Point number in sequence	I4
4	10	Point type (=P)	A1
5	11 to 16	Point latitude (north, +; south, −)	F6.2
6	17 to 23	Point longitude (east, +; west, −)	F7.2
7	31 to 34	See item 3	
8	35	See item 4	
9	36 to 41	See item 5	
10	42 to 48	See item 6	
11	56 to 59	See item 3	
12	60	See item 4	
13	61 to 66	See item 5	
14	67 to 73	See item 6	

2.3.1.4 Affiliated Sets File

In section 2.3.1.2, which described the Service Area file, reference was made to an optional entry for each service area that allows the user to indicate that a service area is a member of an affiliated set of service areas that are to be served from a single space station location. In the Service Area file, membership in such a set was signified by placing the same integer numeric code in the appropriate service area records. The result of specifying such membership in an affiliated set was stated to be that all such service areas would be treated in an all or nothing manner in the determination of compatible groups of service areas and the generation of allotted arcs; that is, either all affiliated member service areas must be included in a compatible group of service areas or no members must be included.

The purpose of the Affiliated Sets file is to aid in implementation of all or nothing treatment of member service areas. Each record of the Affiliated Sets file contains an integer numeric code, corresponding to the code specified on the records of the member service areas within the Service Area file. The integer codes should be in ascending numeric order starting with one (1) and proceeding through to the number of separate affiliated sets (i.e., 1, 2, 3, etc.). This integer code is followed by a three character code, for the affiliated set of service areas, that will replace individual service area codes within a compatible grouping. The final item in each record is an integer, equal to the number of individual service areas that are to be included as members in the affiliated set. The format of each record is described in table 2.3-4.

The Affiliated Sets file may contain up to 25 such records. As each record is of fixed 80-byte length, the Affiliated Sets file may occupy up to 2 kilobytes of memory.

The user is referred to the *NASARC* (*Version* 2.0) *Technical Manual* for further discussion of the affiliated set concept, and to section 3.2.4 herein for further directions on use of the concept in construction of NASARC (Version 2.0) input data.

TABLE 2.3-4—FORMAT FOR DATA IN AFFILIATE SETS FILE

Item	Column	Description	Format
1	2 to 3	Numeric code for affiliated set (= 1, 2, 3, ...)	I2
2	5 to 7	Three-character code for affiliated set	A3
3	9 to 10	Number of member service areas in set (=2 or more)	I2

2.3.1.5 Input Data File

The Input Data file, unlike other input files discussed, is not created prior to use of the NASARC modules. Rather, the Input Data file is created via execution of the NASARC0 module.

The Input Data file will contain a series of records created primarily, though not exclusively, in response to the user's interactively supplied answers to a series of input prompts issued by the NASARC0 module. In addition to these records, the Input Data file will contain several flags indicating various conditions of the input to the NASARC1, NASARC2, and NASARC3 modules. These flags are the product of file checking and correlation operations performed by the NASARC0 module and are thus only indirectly influenced by the user's input. Finally, the Input Data file will also contain the four constants used in the calculation of the length of the allotted arcs to be given to service areas; as mentioned previously, these constants are extracted from the Point Sets file.

Further information on correct responses to the interactive prompts mentioned previously may be found in section 3.2.5 herein along with further details on the remainder of the Input Data file.

As the Input Data file contains 18 records of fixed 80-byte length, the file will occupy 1.44 kilobytes of memory.

2.3.1.6 Ellipse File

The Ellipse file, required by the NASARC1 and NASARC3 modules as input, contains ellipse data for 222 service areas. For each area, the Ellipse file contains ellipses at all possible integral locations within the service area's visible arc (0° elevation angle). This file is furnished on the magnetic tape containing the NASARC (Version 2.0) software package. Further information on the technical basis of this file may be obtained in Section 3.1.1.3 of the *NASARC Version* 2.0 *Technical Manual.*

It is important to note that the role of the furnished Ellipse file may also be fulfilled by any ellipse requirements file containing similar data; it is not necessary that the Ellipse file included on the tape be used exclusively. However, any such file should conform to the format conventions described in this section in order to be used successfully with the NASARC (Version 2.0) software package. Each record of the Ellipse file must contain the three-character service area code corresponding to the ellipse, the satellite longitude at which the ellipse was calculated, the ellipse aimpoint latitude and aimpoint longitude, the orientation angle of the ellipse, and the ellipse major and minor axis beamwidths. These elements must appear in each record in the format described in table 2.3-5. The records within the Ellipse file must also conform to a specific ordering. Records are arranged in blocks corresponding to service areas; ellipses for a given service area must all appear as consecutive records within the same block of data. Within a block of ellipses corresponding to a given service area, the ellipse records should be arranged by longitude (columns 10 to 15) in a west-to-east direction over the service area's service arc. Ellipses within each block should represent ellipses calculated at 1° intervals across the service area's possible service arc; that is, if the service arc crosses the 180° meridian, the ellipse calculated at 180° east longitude should be immediately followed by the ellipse calculated at −179° east longitude. Further, the blocks of ellipse data corresponding to individual service areas should appear with service area codes in alphabetical order. The user will recall that this ordering corresponds to the ordering for the service-area/service arc file, discussed in section 2.3.1.2 herein.

The Ellipse file furnished with the NASARC package, which contains 31,844 records of 80 bytes each, occupies a total of 2.5 megabytes of storage.

TABLE 2.3-5—FORMAT FOR ELLIPSE DATA

Item	Column	Description	Format
1	2 to 4	Three-character service area code	A3
2	10 to 15	Satellite longitude for which ellipse was calculated, deg	F6.1
3	24 to 29	Aimpoint latitude for ellipse, deg	F6.2
4	30 to 36	Aimpoint longitude for ellipse, deg	F7.2
5	38 to 44	Orientation angle of ellipse, deg	F7.2
6	52 to 56	Major axis beam-width, deg	F5.2
7	57 to 61	Minor axis beam-width, deg	F5.2

2.3.2 Intermediate Files

To utilize the NASARC (Version 2.0) software package for planning exercises, it is necessary to execute the NASARC1 module (the grouping program), the NASARC2 module (the arc determination program), and the NASARC3 module (the group arc extension program) over all portions of the geostationary orbit that the user has defined within the Segments file. As results are considered to be final only when all segments of the orbit specified by the user have been examined, it is clear that intermediate results achieved using the NASARC1, NASARC2, and NASARC3 modules in one portion of the arc must be stored for possible future consideration as other portions of the arc are examined.

Thus, intermediate files include those files which are generated and used by the NASARC (Version 2.0) program modules on an interim basis; that is, they are files which contain data that are altered or updated periodically by one or more modules for use by other modules in determining a final, output solution. As such, these files require no user intervention and may be treated as being transparent to the user. However, the user should be aware of the content of each such file and its approximate storage requirements, which are presented in the subsequent sections.

2.3.2.1 Intermediate Segments File

The Intermediate Segments file is identical in format to the Segments file discussed in section 2.3.1.1 and contains similar data—western and eastern longitudinal limits of portions of the orbital arc. However, while the Segments file contains portions of the orbit that are yet to be operated on by the NASARC1, NASARC2, and NASARC3 modules, the Intermediate Segments file contains portions of the orbital arc that have already undergone analysis by these three modules. At the conclusion of the analysis—when all portions of the orbit have been examined—the Intermediate Segments file will be identical to the original Segments file constructed by the user.

As each segment of orbit within the user's Segments file is encountered by NASARC1, it is copied to the bottom of the Intermediate Segments file. The Intermediate Segments file is then utilized by the NASARC2 module to determine the cumulative orbital arc analyzed in order to rearrange prior allotted arcs for the accommodation of newly allotted arcs within the orbit. Finally, the Intermediate Segments file is used by the NASARC3 module to restore the user's original Segments file after all portions of the orbital arc listed have been examined for potential arc allocation.

The Intermediate Segments file may contain up to 40 records of fixed 10-byte length. Thus, the file may occupy up to 3.2 kilobytes of memory.

2.3.2.2 Groups File

The Groups file, which is generated by executing the NASARC1 module, is utilized as input by the NASARC2 module.

The Groups file contains a complete listing of all service areas, and their corresponding service arcs, processed within the most recently examined portion of the orbit. It also contains a complete listing of all compatible groups of service areas (and arc segments over which they exist) that have been found by the NASARC1 module. The NASARC2 module will choose from this list in constructing sets of allotted arcs.

Actual storage requirements for this file are somewhat difficult to predict since the number of records produced by the NASARC1 module will depend on both the number of service areas processed and the set of technical parameters supplied as input. However, NASARC1 (Version 2.0) is capable of generating 63,000 groups and arc segments; the list of service areas processed may occupy up to 300 records of the output file. As each record is of fixed 80-byte length, this file may occupy up to 5.0 megabytes of storage.

2.3.2.3 Intermediate Allotted Groupings File

The Intermediate Allotted Groupings file, which is generated by the NASARC2 module, is utilized as input by the NASARC1 module and may be updated by the NASARC3 module.

As stated in the previous section, the NASARC2 module will select groups of compatible service areas, from the list of groups and arc segments produced by the NASARC1 module, and attempt to allot portions of the orbit to such groups. When the NASARC2 module finishes making such selections, the selections are appended to the list of selections that may have been made in processing prior portions of the orbit within the Segments file. Prior selections are also subject to revision by the NASARC2 module, should revision become necessary to accommodate the allotted arcs of new groups of administrations. Thus, the Intermediate Allotted Groupings file contains all the compatible groups of service areas that have received allotted portions of the geostationary arc via the NASARC2 module. The file also contains, for each such group of service areas, the boundaries of the portion of arc that they have received (the *allotted arc*) as well as the boundaries of the segment of orbital arc over which each such grouping has been found to exist thus far (the *group arc*).

This file will be examined by the NASARC3 module, which will determine if any group arc may be extended into the next portion of the orbit to be examined by NASARC1. If such extension is possible for any group within the file, the Intermediate Allotted Groupings file will be modified to reflect such revised group arcs. The Intermediate Allotted Groupings file will then be utilized by NASARC1, to eliminate service areas that have already received allotted arcs in prior steps from consideration in the next portion of the arc to be analyzed.

The file may contain up to 150 records of 80 bytes each; therefore, the file may occupy up to 12 kilobytes of memory.

2.3.2.4 Unallotted Groups File

The Unallotted Groups file is utilized as both an input and output file for the NASARC2 module.

As stated earlier, the NASARC1, NASARC2, and NASARC3 modules will be exercised repeatedly over the portions of the geostationary orbital arc that the user has defined within the Segments file. This is a cumulative process, which results in the gradual development of a set of groups of compatible service areas and their allotted arcs, over the span of orbital arc locations defined by the user's portions within the Segments file.

At the end of the NASARC2 arc allotment process for a particular segment (and cumulative arc), there may still exist unallotted groups whose group arc extends to one or both edges of this cumulative arc. The Unallotted Groups file saves all groups whose group arc adjoins an edge of any previous cumulative arc. The file also contains the group arc for each such group and the number of member service areas of each group. Since these groups have the potential of existing beyond the bounds of the current cumulative arc, they will appear in the NASARC1 output during processing of a future portion of arc in the Segments file. If they appear in the NASARC1 output groups list, their group arcs will appear to extend only as far as the bounds of the segment currently being processed. Hence, in order to work with complete group arcs, it is necessary to save the unallotted groups just described and merge them with the groups output by NASARC1 in processing subsequent segments. This is accomplished at the start of each NASARC2 run by appending the unallotted groups to the end of the present NASARC1 groups and combining the group arcs of duplicate groups where they are contiguous. The maximum amount of group arc that exists within the current cumulative arc is then identified for each group.

Storage requirements are somewhat difficult to predict since the size of the file will depend on user-supplied technical parameters; however, 4 megabytes should be a sufficient storage allocation.

2.3.2.5 Intermediate Selection File

The Intermediate Selection file is created and modified by the NASARC2 module. It contains information generated by the NASARC2 module during each step of the arc determination process. The file contains cumulative information in the sense that such information is gathered and retained within the file for each user-specified portion of the orbit that undergoes analysis. As a new portion is analyzed, the information generated is added to existing information generated during performance of the arc determination process on previously analyzed portions of the orbital arc. Thus, by examining the contents of this file, the user may follow the decision-making of the NASARC2 arc generation process as applied to all portions of the arc analyzed.

The file contains information related to the current status of the analysis and to the decision-making processes of arc determination. The current status of the analysis is reflected by the number of user-specified portions of the orbit that have been processed, the longitudinal edges of the cumulative orbital arc span that has been analyzed, and the edges of the portion of the orbit most recently examined. For informational purposes, the data contained in the Input Data file are echoed within the Intermediate Selection file; also included is a list of service areas, service arc boundaries, and any buffer arc lengths included in the most recent analysis of a portion of the arc.

The course of the decision-making processes involved in arc determination may be followed by examining various ordered lists generated by the NASARC2 module. A list of *critical* service areas is produced; it is ordered by the number of occurrences of each such service area in groups contained in the most current list of compatible groups and group arc segments. That service area occurring in the fewest such groups will appear at the top of the list. This list will also contain the priority (P1, P2, or P3) with which each service area is to receive an allotted arc length. A list of *critical groups*—compatible groups of service areas which contain the critical service area—is also generated and ordered by group arc boundaries, number of service areas included in the group, and the sum of frequency of occurrence within any group of each critical group member. The frequency of occurrence of any service area within a group is calculated by examining the most current list of compatible groups of service areas. This list is periodically updated as service areas receive allotted arc lengths. While the list itself is not presented in the file, information related to updating this list is presented in the file—for example, the number of groups contained in the list before and after updating, the number of groups from which members were extracted (due to receiving an allotted arc length), and the number of groups (if any) eliminated by selection of the critical group to receive an allotted arc. The updated list is searched to determine if elimination of any service area not a member of the critical group has occurred; such service areas are listed within the Intermediate Selection file as are those service areas for which no allotted arc can be found. Finally, a complete list of groups selected, their arc length requirements, and received allotted arc boundaries is generated.

Exact storage requirements for this file are difficult to predict. Once again, storage requirements will depend to a great extent on the scenario undergoing analysis. However, 4 megabytes for records of fixed 80-byte length is felt to be a sufficient allocation for most scenarios.

2.3.3 Output Files

Output files are those produced by one or more modules of the NASARC software package that are used to store results at the conclusion of an exercise of the NASARC modules on a particular scenario. These results may be those of a successful exercise which are output to the NASARC Report file described in section 2.3.3.1 or an unsuccessful exercise—an exercise in which data input errors have resulted in premature termination of one or more modules—which are output to the Error Message file described in section 2.3.3.2.

2.3.3.1 NASARC Report File

As stated previously, the NASARC Report file is produced at the conclusion of a successful exercise of the NASARC package on a particular scenario. ("Successful exercise" refers only to the fact that all modules have executed successfully on the input data provided; the user may still wish to improve upon the results obtained by

altering his or her input data.) The NASARC Report file is produced by the NASARC3 module at the conclusion of examination of all portions of the orbit specified by the user within the Segments file.

The NASARC Report file contains complete information on all scenario input data such as a complete list of service areas considered, their associated service arcs, and associated optional parameters supplied by the user for each service area; a list of all user-specified portions of the orbital arc that have been examined; and a list of all interactively specified input parameters. If applicable, additional information is printed about affiliation of service areas.

Following a complete description of the input supplied to the program, the NASARC Report file presents the results of exercising the NASARC1, NASARC2, and NASARC3 modules on the data just described. First, a table of compatible groups of service areas selected to receive allotted arcs is presented, containing the groups selected, their allotted arc boundaries, their group arc boundaries, the length of their allotted arc, and the number of member service areas contained in each group. Overall results, such as the total amount of orbital arc utilized for allotted arcs, the number of groups of service areas that received such allotted arcs, the number of service areas that received such allotted arcs, and (if any) the number of service areas that did not receive allotted arcs, are presented with the table. Further information, on a service area by service area basis, is presented following the table. Finally, a pictorial representation of the allotted portions of the orbit and the groups of service areas to which they have been allotted is produced, presenting a visual summary of the scenario results.

Exact storage requirements of the NASARC Report file are, once again, dependent on the scenario supplied by the user. However, an allocation of 160 kilobytes for fixed-length, 132-byte records is sufficient for most scenarios.

When printing the NASARC Report file, it is suggested that the carriage control option be selected, as this file contains carriage control characters and the resulting document will be easier to read.

2.3.3.2 Error Message File

The Error Message file can be written to by any of the NASARC0, NASARC1, NASARC2, or NASARC3 modules under a variety of circumstances. Generally, these circumstances represent errors in data input that result in a premature termination of the appropriate modules. Should the user encounter such a premature termination, the Error Message file is an aid to discovering the source of the problem. Generally, error messages that are written to the Error Message file are also written to the user's terminal; the file provides a record of such messages for consideration at the user's leisure.

As errors that produce error messages are generally of sufficient severity to result in halting execution of the program, the error message file will almost always contain only one such message. Thus, a storage allocation of 0.8 kilobyte for fixed-length, 80-byte records should be adequate.

3.0 USE OF NASARC SOFTWARE PACKAGE IN PLANNING EXERCISES

This section provides the user with the information necessary to utilize the NASARC (Version 2.0) software package for generation of predetermined arcs for allotment planning exercises. Input (NASARC0), grouping (NASARC1), arc-determination (NASARC2), and group arc extension (NASARC3) program structures are briefly discussed, with the aid of flowcharts also provided in this section. Guidelines for preparation of input files are given as are suggestions for interactively input technical parameter values. Suggestions for utilization of ORBIT-II in conjunction with NASARC are also given. Finally, a complete list of program-generated error messages is given, with information on possible causes of such errors.

It is suggested that the user refer to the *NASARC* (*Version* 2.0) *Technical Manual* for detailed information on the technical basis of the NASARC (Version 2.0) software package. It is also suggested that, if he or she has not done so, the user refer to section 2.0 of this manual for information on input and output file structures and formats as this information will greatly aid the user in constructing new files.

3.1 Overview of NASARC Procedure and Program Structures

During the development of the NASARC (Version 2.0) software package, it was recognized that, for the software to be useful for planning exercises involving large numbers of service areas, a *piecewise* approach to allotting orbital arcs would have to be applied to the geostationary orbital arc. The NASARC procedure allows the NASARC1, NASARC2, and NASARC3 modules to be applied in such a piecewise approach, to a user-specified portioning of the orbital arc into individual segments of arc to be successively examined. The user is referred to figure 3.1-1, which presents a flowchart of the NASARC procedure, and to figure 3.1-2, which presents a flowchart of the interaction between modules.

Prior to use of the NASARC1, NASARC2, and NASARC3 modules within a portion of the orbit, it is necessary to collect data from the user, and verify the input data supplied in external files, in order to assure that the NASARC1, NASARC2, and NASARC3 modules will be able to execute successfully. These functions are performed by the NASARC0 module—the *input* program. The NASARC0 module is utilized once (see figs. 3.1-1 and 3.1-2); the data that are collected and verified will then be utilized over all portions of the orbit to be examined for the given scenario.

Within each segment of the arc examined within the NASARC procedure, several major functions must be performed in order to obtain allotted arcs for service areas. First, all possible compatible groupings of service areas and the arc spans over which each such grouping exists (the group arc) must be determined within the portion of the orbit currently being examined. This function is accomplished by the NASARC1 module—the *grouping* program. Next, selections of compatible groups and allotted arcs must be made in a manner which includes as many service areas as possible and which provides each chosen group with an allotted arc within its group arc. This function is accomplished by the NASARC2 module—the *arc determination* program. Finally, at the conclusion of the arc determination process for the current portion of the orbit, groups of service areas that have been selected to receive allotted arcs within their group arcs must be examined in order to determine if their group arcs may be extended into the portion of the orbit to be analyzed next. This step is necessary in order to provide as much flexibility as possible in remaining portions of the orbit when exercising the arc determination procedure, as the procedure may need to adjust previously allotted arcs in order to accommodate new allotted arcs. This function—the extension of group arcs for possible future use—is performed by NASARC3—the *group arc extension* program.

A flow chart illustrating the sequence of, and interaction between, the NASARC0, NASARC1, NASARC2, and NASARC3 modules appears in figure 3.1-2. The data-gathering and verification operations performed by the NASARC0 module are illustrated in the flowchart appearing in figures 3.1-3(a) to (d). The operations of the grouping program—the NASARC1 module—are described by the flowchart contained in figures 3.1-4(a) to (f); certain operations are illustrated in more detail in figures 3.1-5(a) and (b) and 3.1-6. Processes of the NASARC2 module—the arc determination program—are described in the flowchart in figures 3.1-7(a) to (d); certain processes are illustrated in the flowcharts in figures 3.1-8(a) and (b), 3.1-9, 3.1-10, and 3.1-11. Finally, the operations performed in NASARC3-the group arc extension program—are illustrated in the flowchart in figures 3.1-12(a) to (e). These flowcharts will be referred to throughout the remainder of this section when the NASARC0, NASARC1, NASARC2, and NASARC3 modules are described. Where possible, references will also be made to specific subroutine names; the user will recall that complete lists of subroutine names for the NASARC0, NASARC1, NASARC2, and NASARC3 modules appear in tables 2.2-2, 2.2-3, 2.2-4, and 2.2-5, respectively. (Text resumes on page 53.)

The NASARC EXEC Procedure

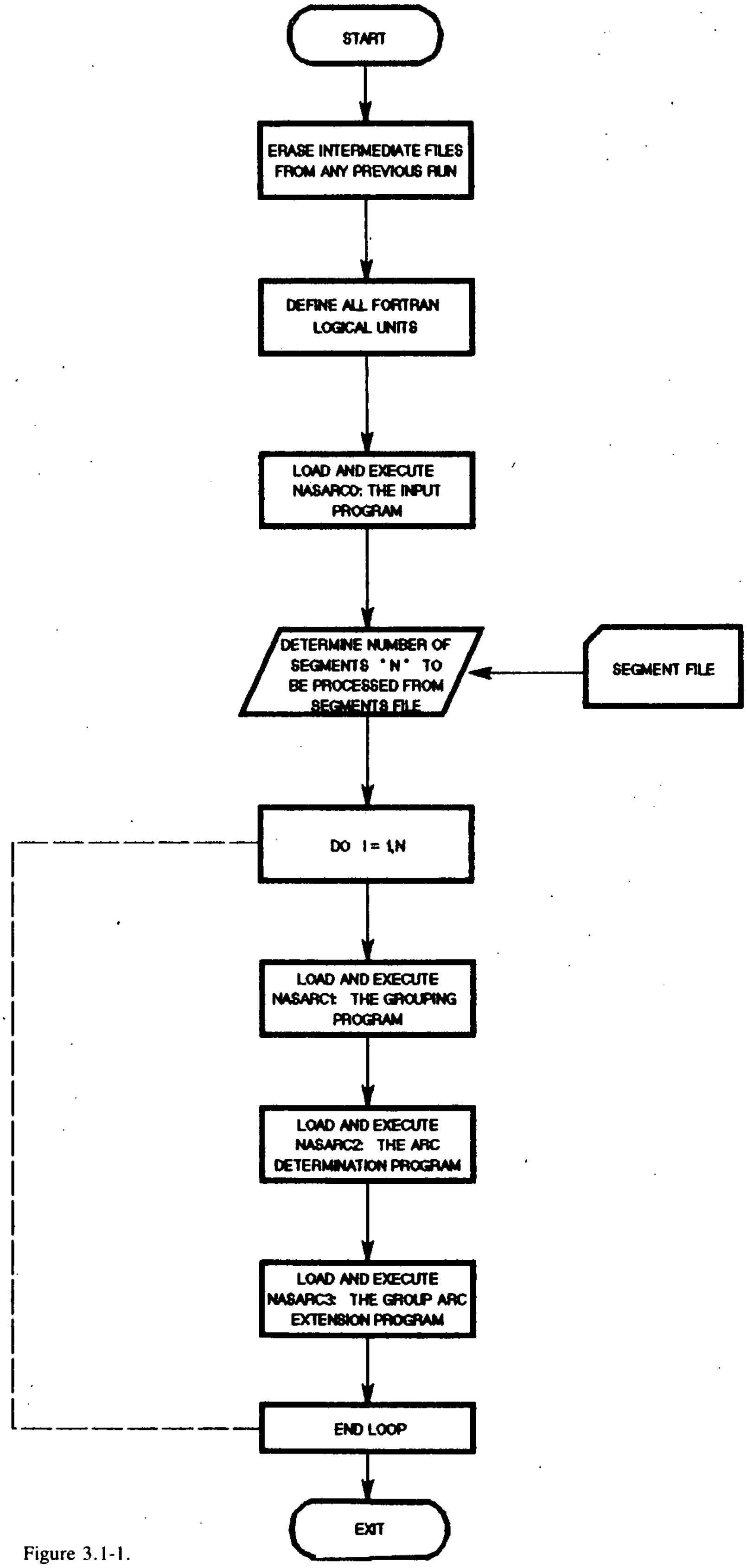

Figure 3.1-1.

NASARC Program Module File Overview

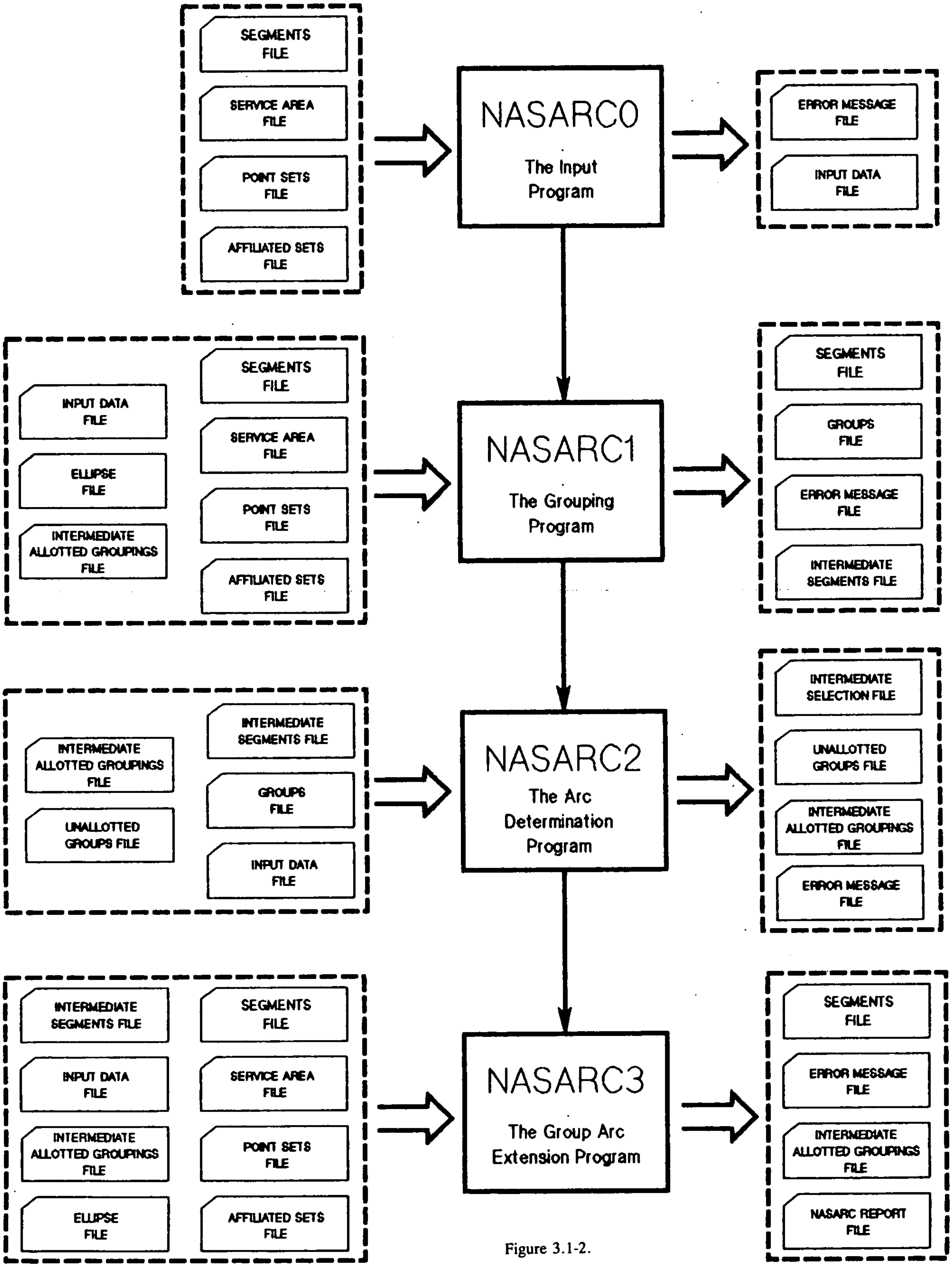

Figure 3.1-2.

NASARCO -- The Input Program

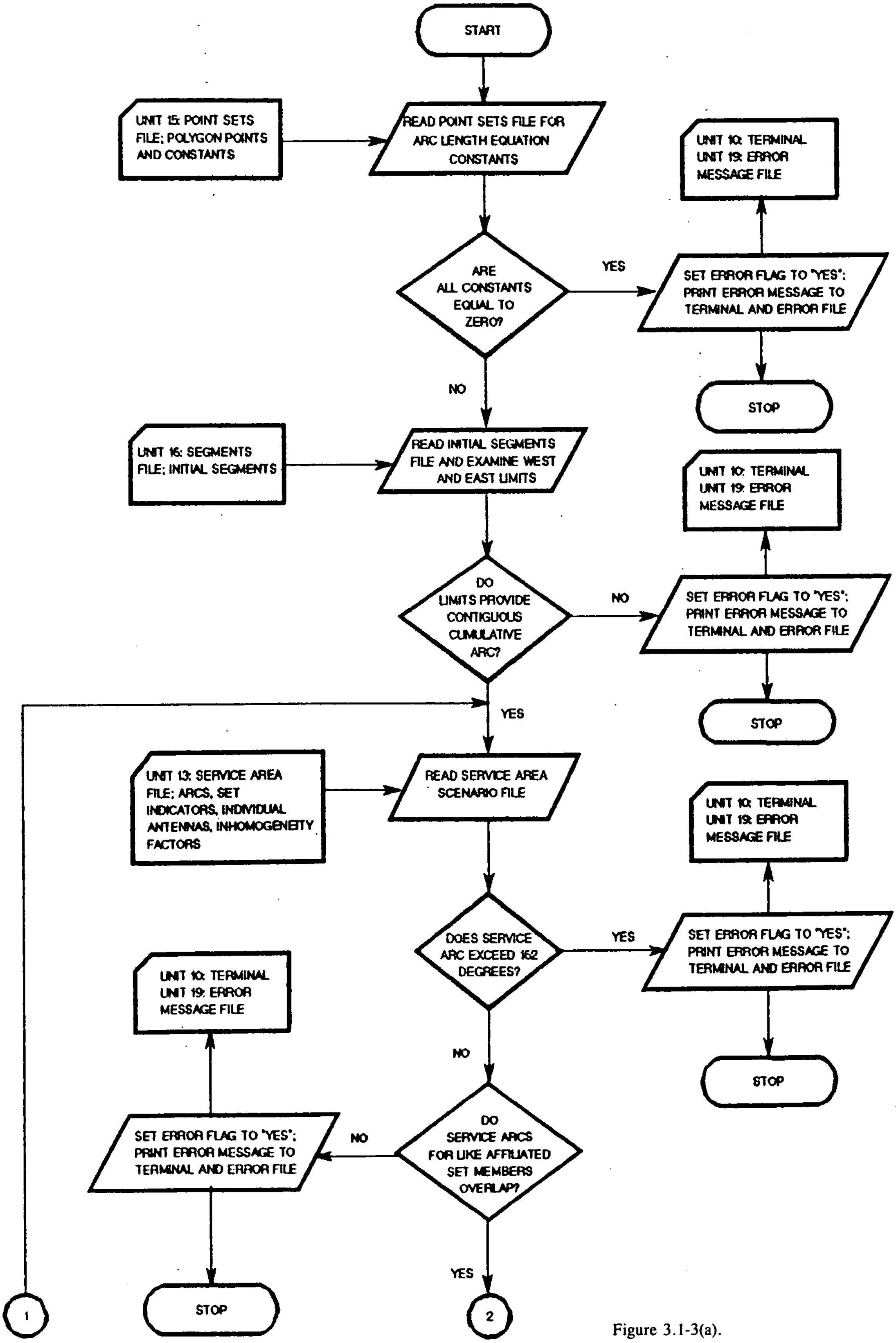

Figure 3.1-3(a).

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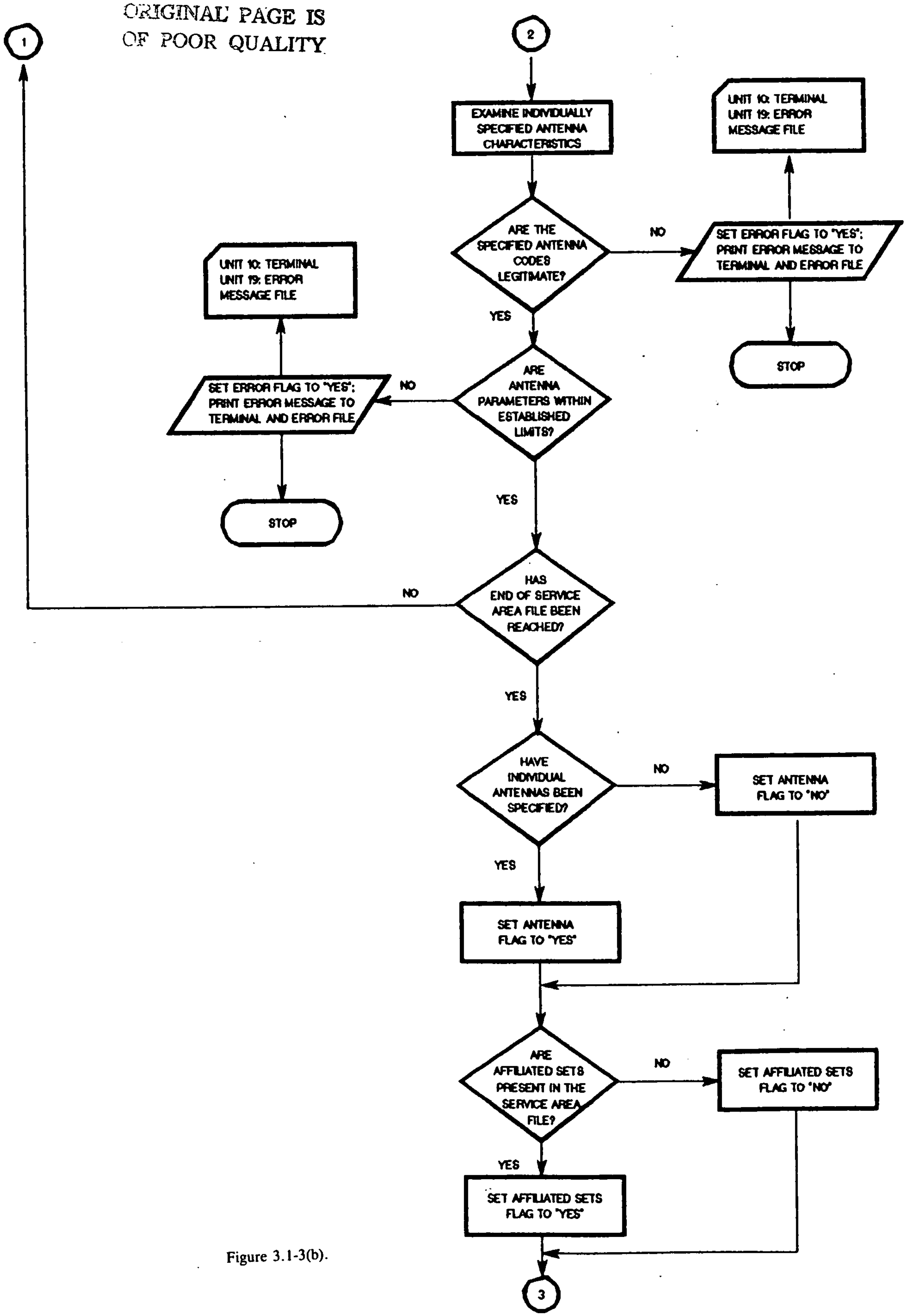

Figure 3.1-3(b).

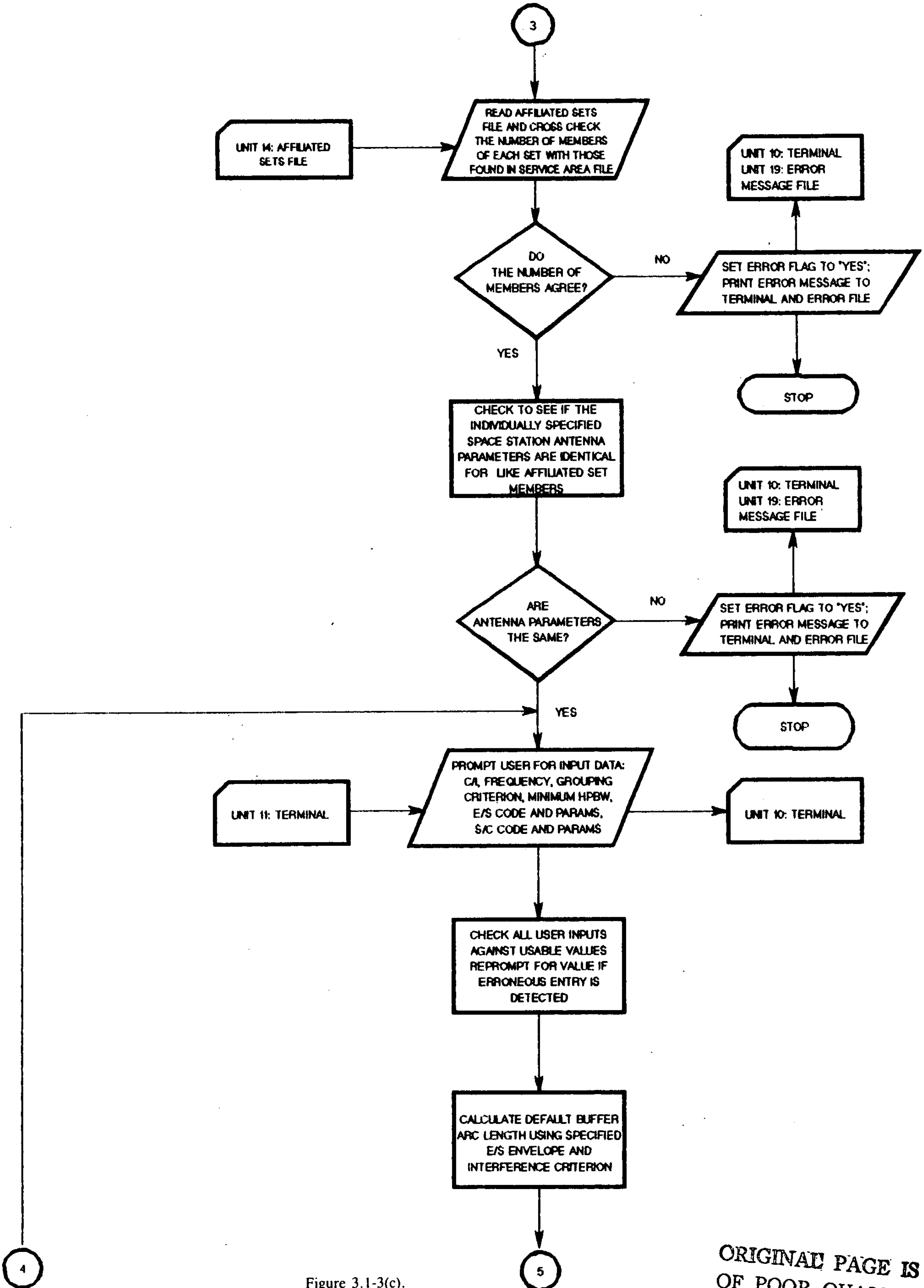

Figure 3.1-3(c).

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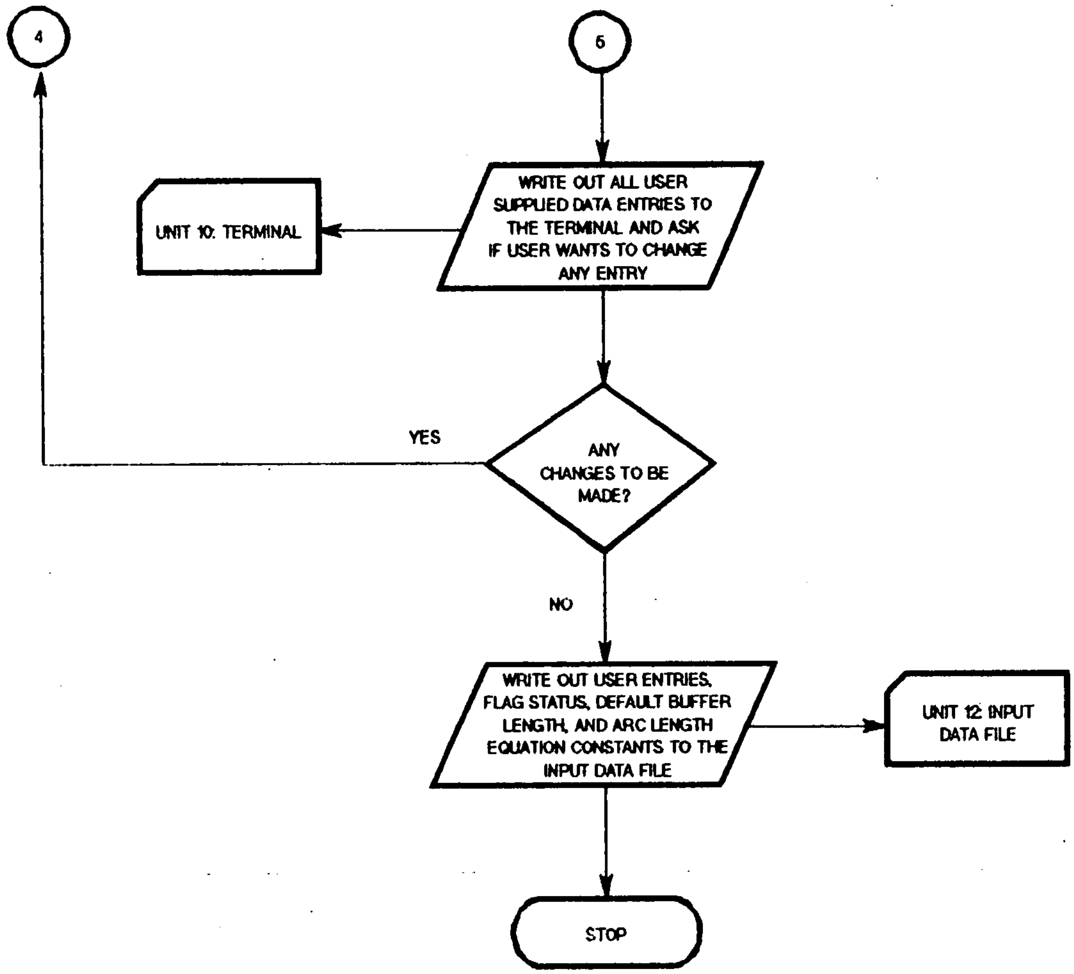
4
6
WRITE OUT ALL USER SUPPLIED DATA ENTRIES TO THE TERMINAL AND ASK IF USER WANTS TO CHANGE ANY ENTRY
UNIT 10: TERMINAL
YES
ANY CHANGES TO BE MADE?
NO
WRITE OUT USER ENTRIES, FLAG STATUS, DEFAULT BUFFER LENGTH, AND ARC LENGTH EQUATION CONSTANTS TO THE INPUT DATA FILE
UNIT 12: INPUT DATA FILE
STOP

Figure 3.1-3(d).

NASARC1 -- The Grouping Program

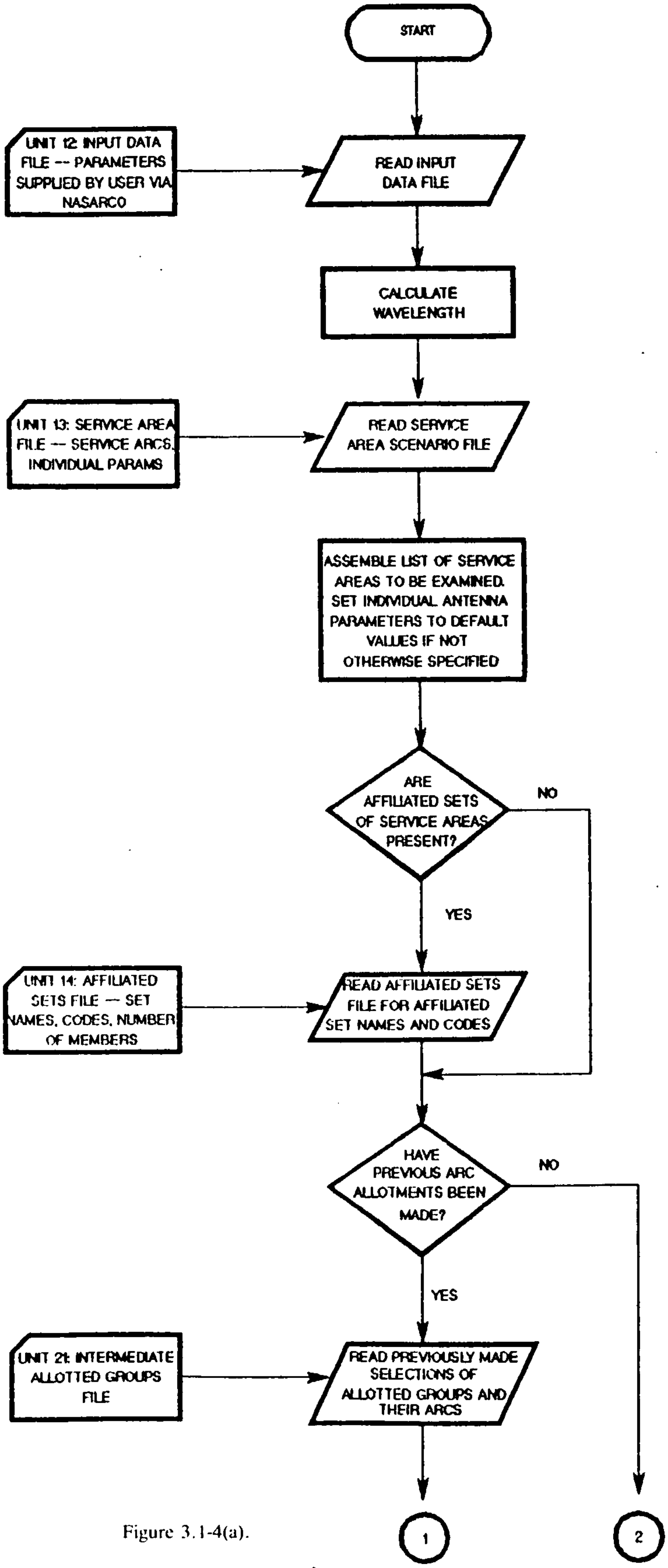

Figure 3.1-4(a).

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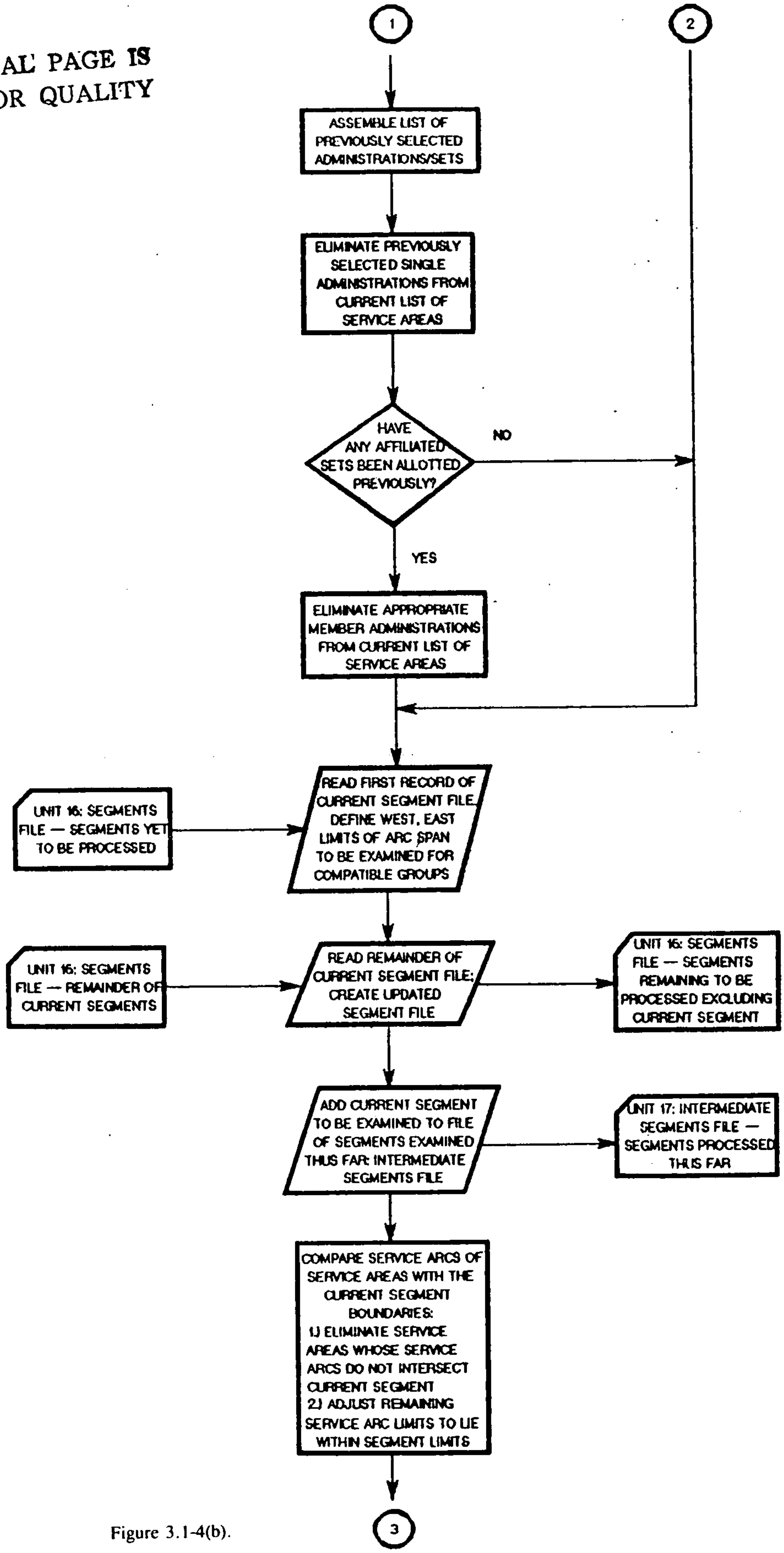

Figure 3.1-4(b).

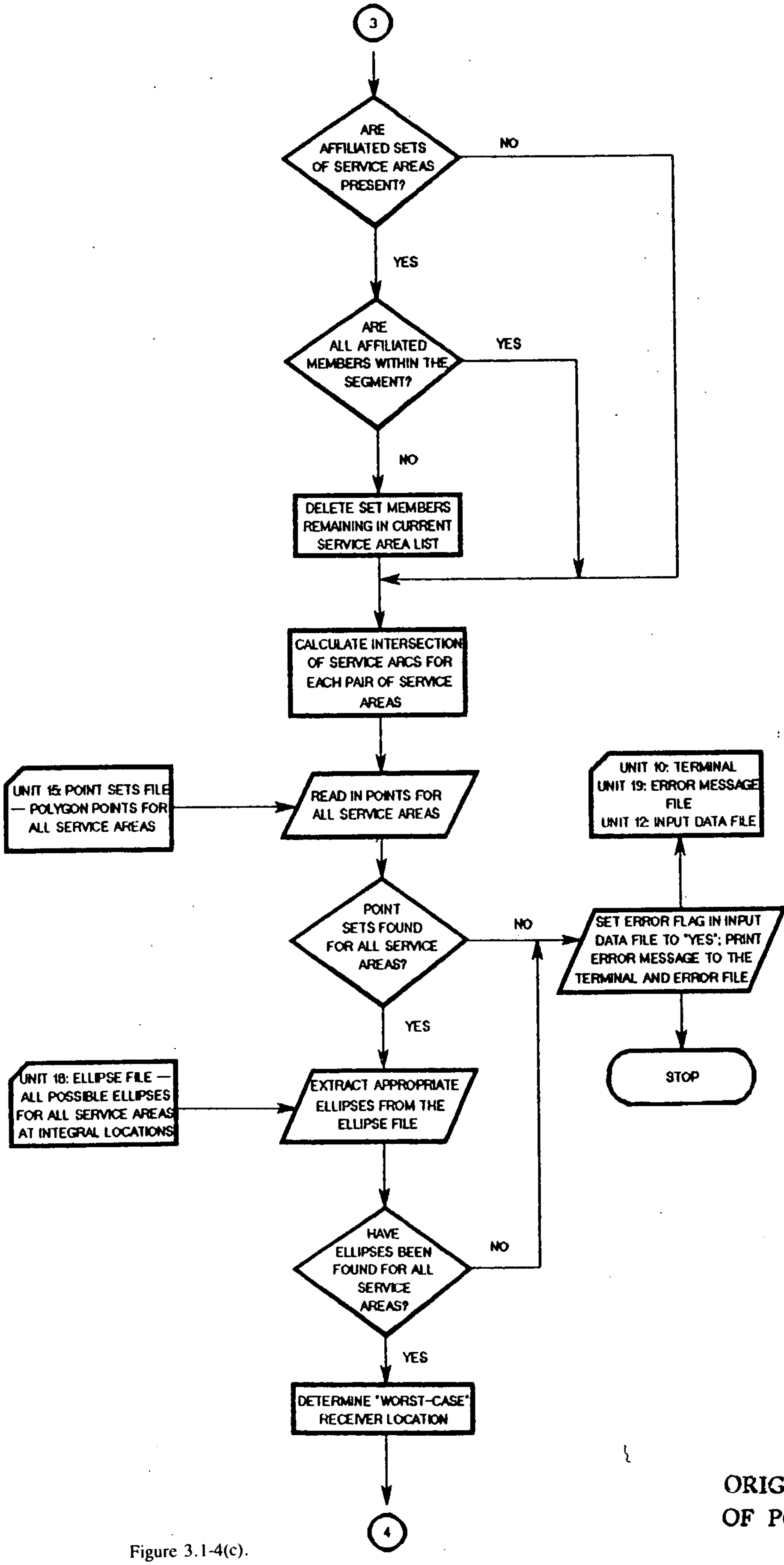

Figure 3.1-4(c).

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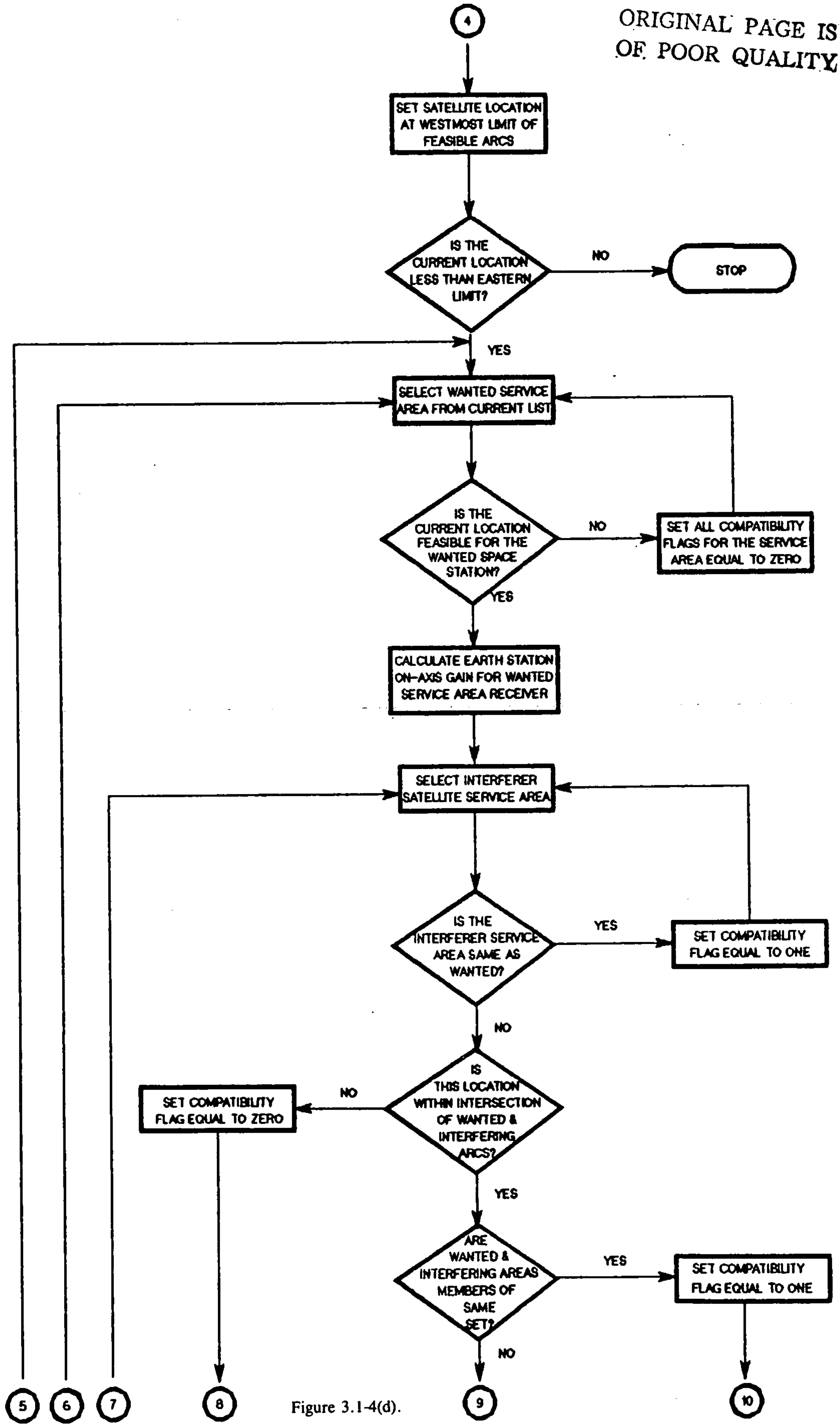
4
SET SATELLITE LOCATION AT WESTMOST LIMIT OF FEASIBLE ARCS
IS THE CURRENT LOCATION LESS THAN EASTERN LIMIT?
NO
STOP
YES
SELECT WANTED SERVICE AREA FROM CURRENT LIST
IS THE CURRENT LOCATION FEASIBLE FOR THE WANTED SPACE STATION?
NO
SET ALL COMPATIBILITY FLAGS FOR THE SERVICE AREA EQUAL TO ZERO
YES
CALCULATE EARTH STATION ON-AXIS GAIN FOR WANTED SERVICE AREA RECEIVER
SELECT INTERFERER SATELLITE SERVICE AREA
IS THE INTERFERER SERVICE AREA SAME AS WANTED?
YES
SET COMPATIBILITY FLAG EQUAL TO ONE
NO
IS THIS LOCATION WITHIN INTERSECTION OF WANTED & INTERFERING ARCS?
NO
SET COMPATIBILITY FLAG EQUAL TO ZERO
YES
ARE WANTED & INTERFERING AREAS MEMBERS OF SAME SET?
YES
SET COMPATIBILITY FLAG EQUAL TO ONE
NO
5
6
7
8
9
10
Figure 3.1-4(d).

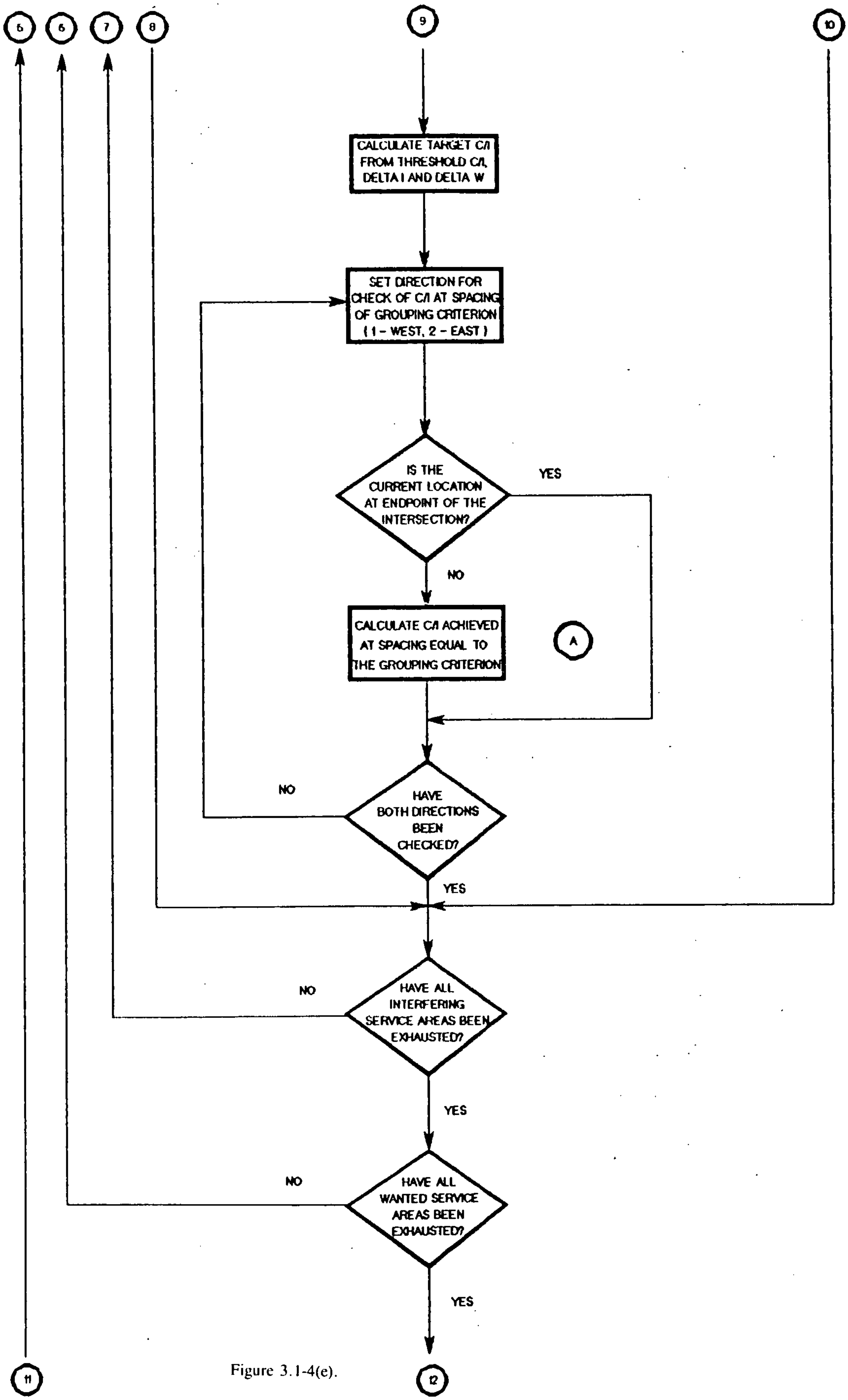
5
6
7
8
9
10
CALCULATE TARGET C/I FROM THRESHOLD C/I, DELTA I AND DELTA W
SET DIRECTION FOR CHECK OF C/I AT SPACING OF GROUPING CRITERION (1 - WEST, 2 - EAST)
IS THE CURRENT LOCATION AT ENDPOINT OF THE INTERSECTION?
YES
NO
CALCULATE C/I ACHIEVED AT SPACING EQUAL TO THE GROUPING CRITERION
A
HAVE BOTH DIRECTIONS BEEN CHECKED?
NO
YES
HAVE ALL INTERFERING SERVICE AREAS BEEN EXHAUSTED?
NO
YES
HAVE ALL WANTED SERVICE AREAS BEEN EXHAUSTED?
NO
YES
11
12

Figure 3.1-4(e).

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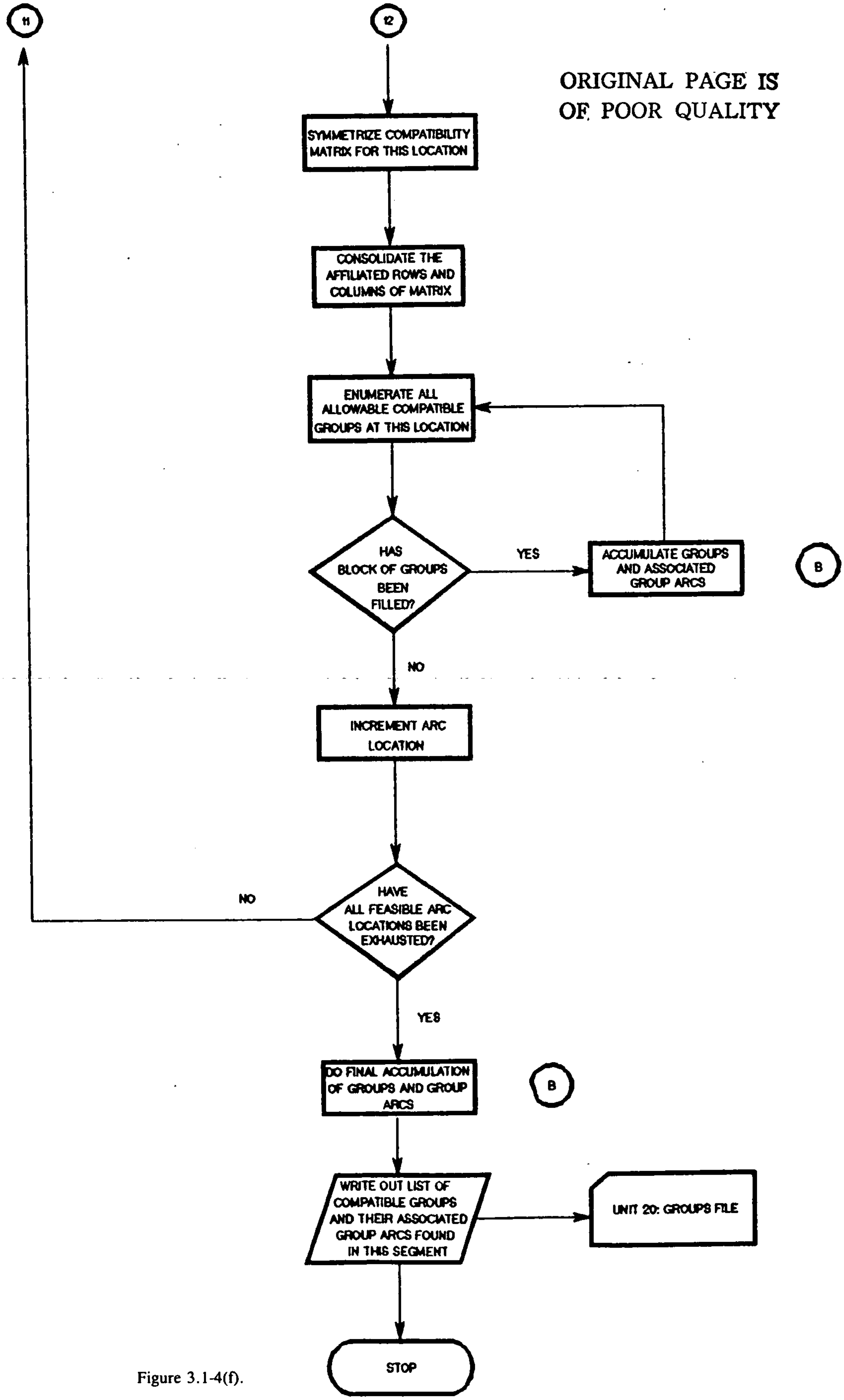

Figure 3.1-4(f).

Verification of Sufficient Space Station Separation at Grouping Criterion

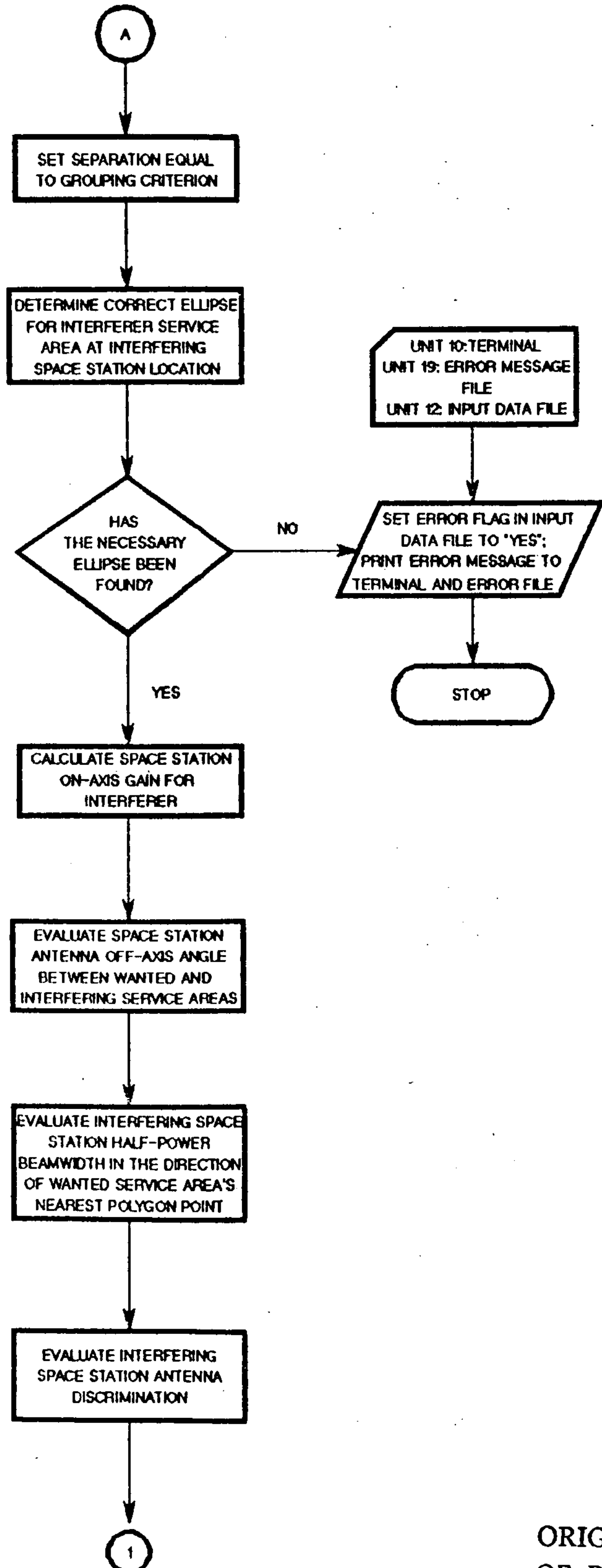

Figure 3.1-5(a).

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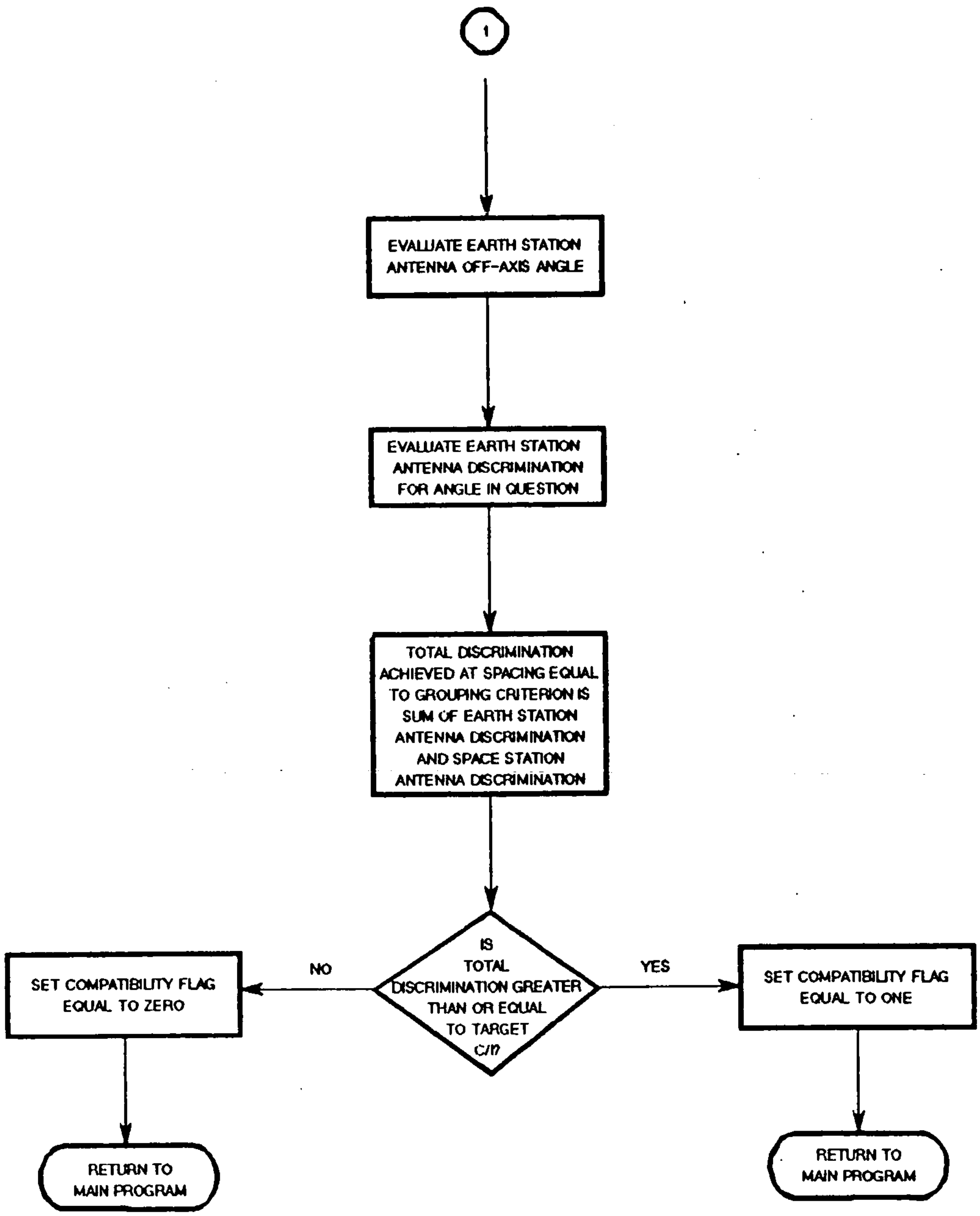
1
EVALUATE EARTH STATION ANTENNA OFF-AXIS ANGLE
EVALUATE EARTH STATION ANTENNA DISCRIMINATION FOR ANGLE IN QUESTION
TOTAL DISCRIMINATION ACHIEVED AT SPACING EQUAL TO GROUPING CRITERION IS SUM OF EARTH STATION ANTENNA DISCRIMINATION AND SPACE STATION ANTENNA DISCRIMINATION
IS TOTAL DISCRIMINATION GREATER THAN OR EQUAL TO TARGET C/I?
NO
YES
SET COMPATIBILITY FLAG EQUAL TO ZERO
SET COMPATIBILITY FLAG EQUAL TO ONE
RETURN TO MAIN PROGRAM
RETURN TO MAIN PROGRAM

Figure 3.1-5(b).

FORMATION OF GROUP ARC SEGMENTS AND CREATION / UPDATING OF MASTER GROUPS LIST

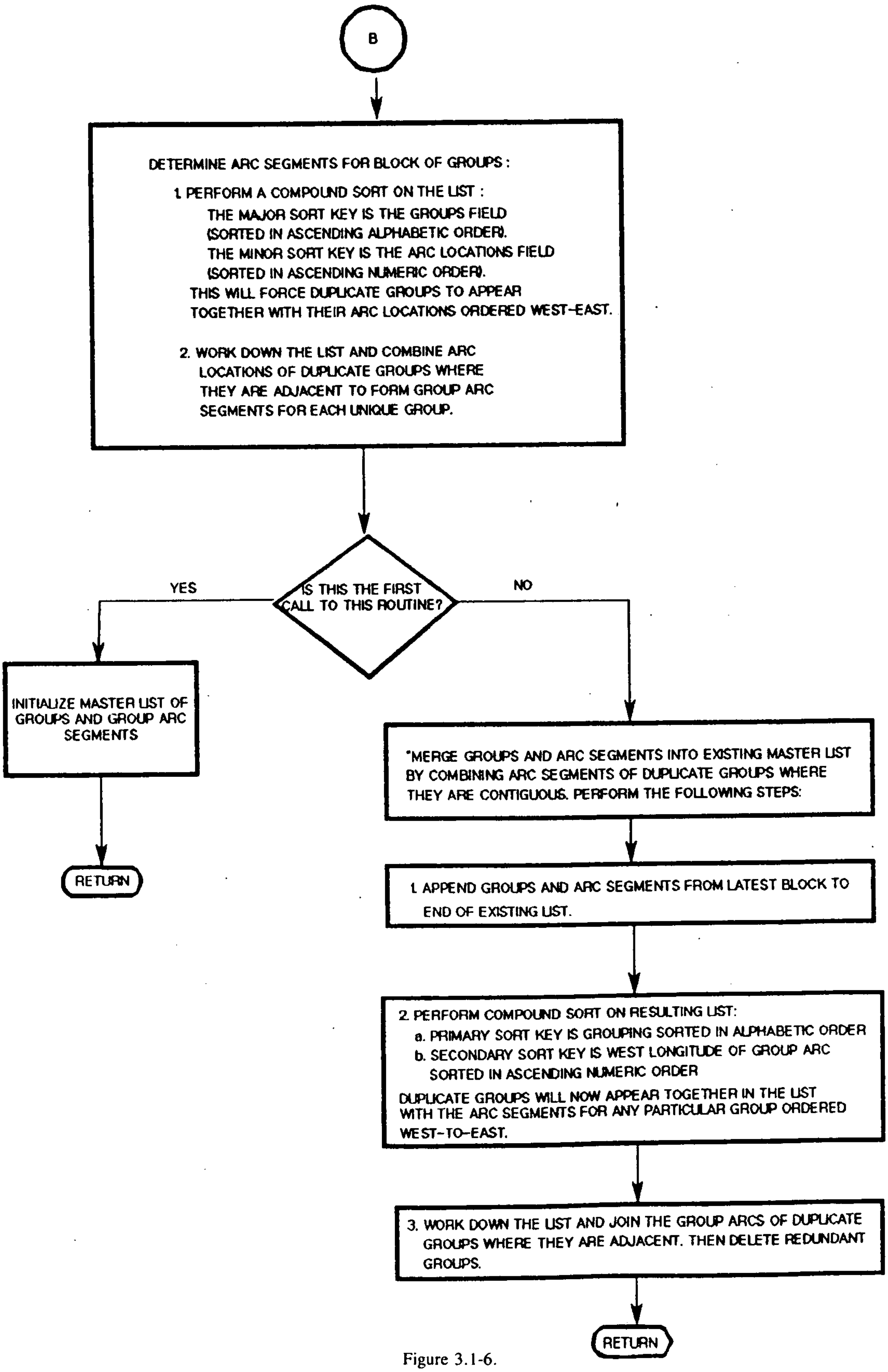

Figure 3.1-6.

NASARC2 -- The Arc Determination Program

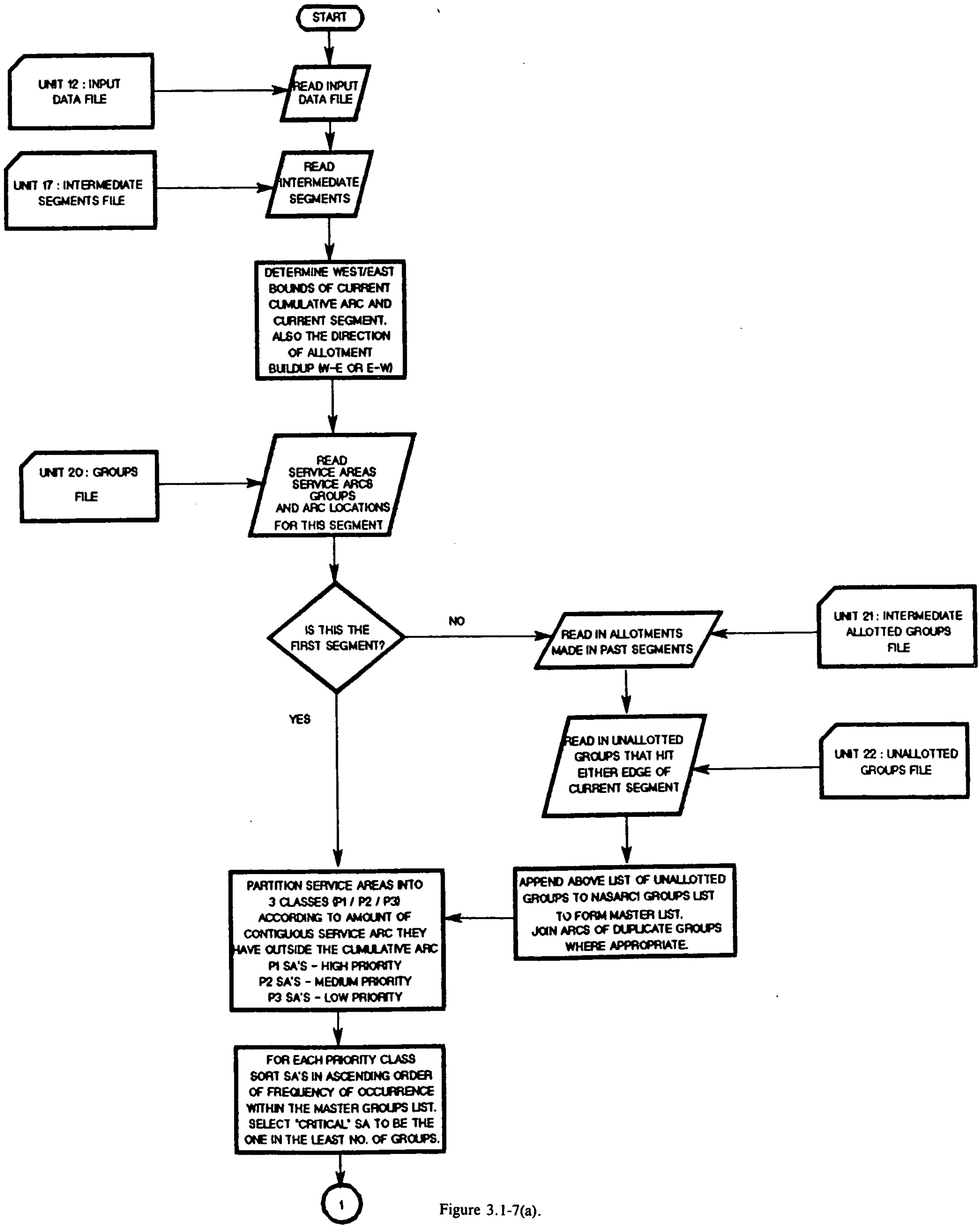

Figure 3.1-7(a).

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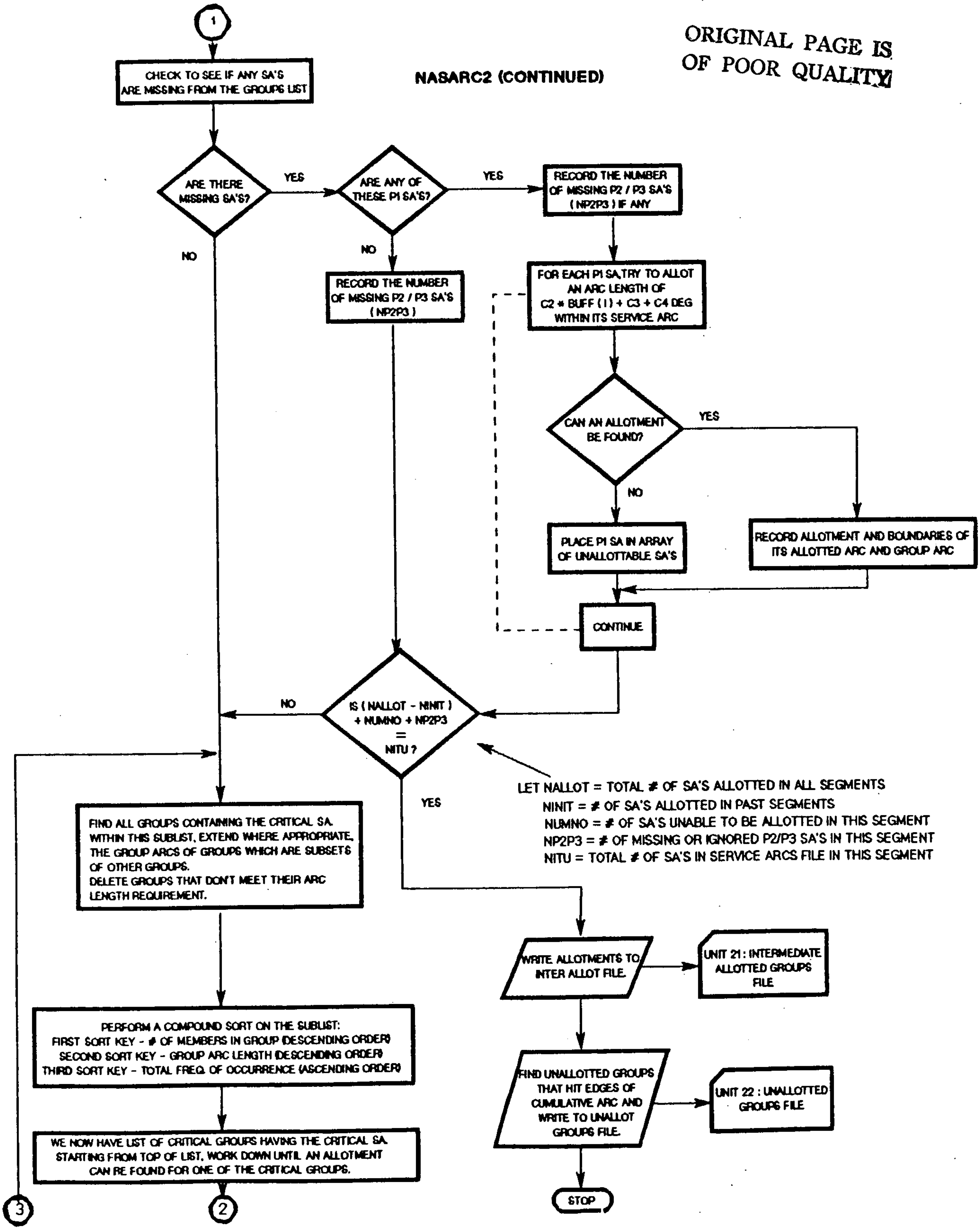
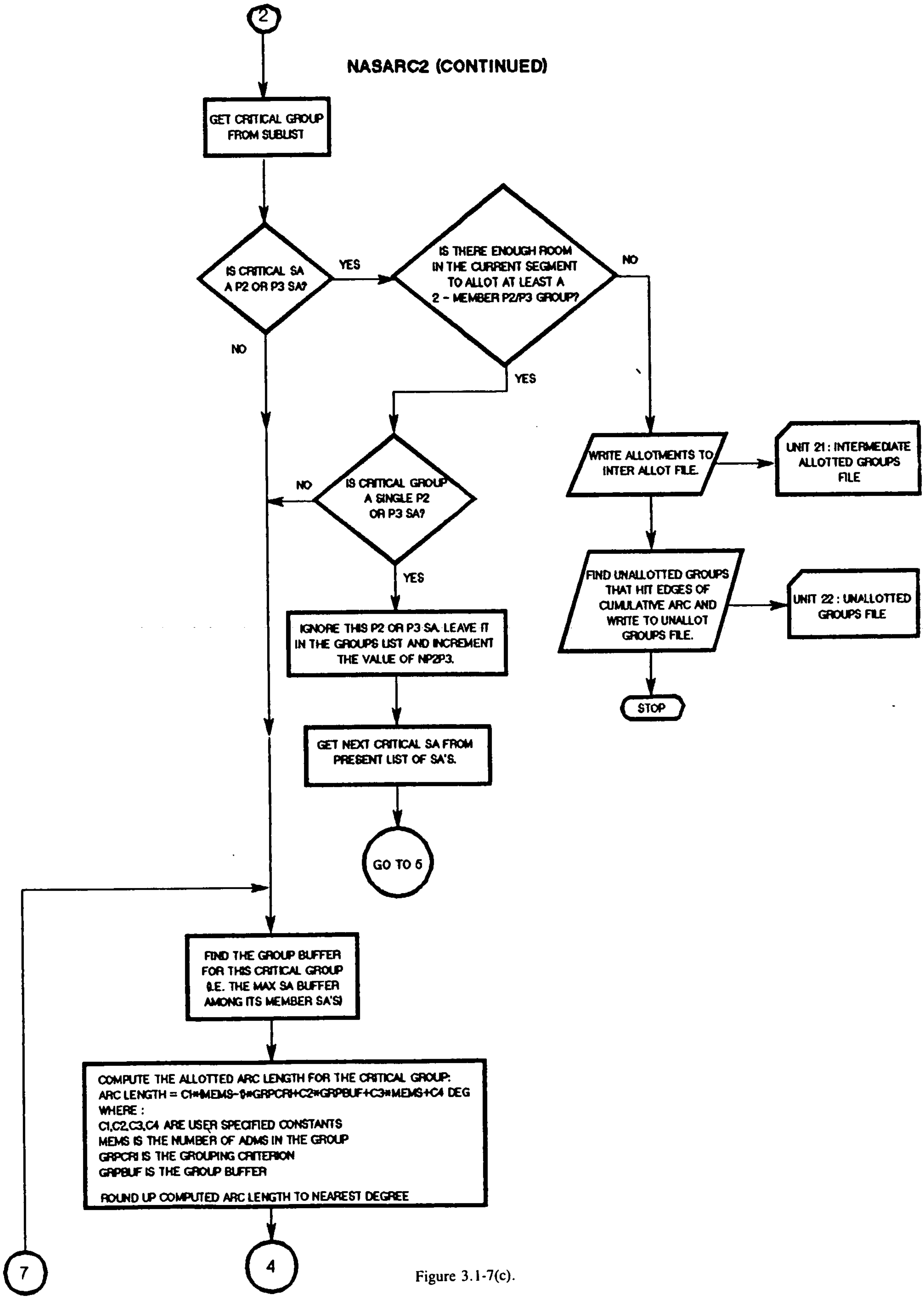


Figure 3.1-7(b).



2
NASARC2 (CONTINUED)
GET CRITICAL GROUP FROM SUBLIST
IS CRITICAL SA A P2 OR P3 SA?
YES
NO
IS THERE ENOUGH ROOM IN THE CURRENT SEGMENT TO ALLOT AT LEAST A 2 - MEMBER P2/P3 GROUP?
NO
YES
WRITE ALLOTMENTS TO INTER ALLOT FILE.
UNIT 21 : INTERMEDIATE ALLOTTED GROUPS FILE
FIND UNALLOTTED GROUPS THAT HIT EDGES OF CUMULATIVE ARC AND WRITE TO UNALLOT GROUPS FILE.
UNIT 22 : UNALLOTTED GROUPS FILE
STOP
IS CRITICAL GROUP A SINGLE P2 OR P3 SA?
NO
YES
IGNORE THIS P2 OR P3 SA. LEAVE IT IN THE GROUPS LIST AND INCREMENT THE VALUE OF NP2P3.
GET NEXT CRITICAL SA FROM PRESENT LIST OF SA'S.
GO TO 5
FIND THE GROUP BUFFER FOR THIS CRITICAL GROUP (I.E. THE MAX SA BUFFER AMONG ITS MEMBER SA'S)
COMPUTE THE ALLOTTED ARC LENGTH FOR THE CRITICAL GROUP:
ARC LENGTH = C1*MEMS-1)*GRPCRI+C2*GRPBUF+C3*MEMS+C4 DEG
WHERE :
C1,C2,C3,C4 ARE USER SPECIFIED CONSTANTS
MEMS IS THE NUMBER OF ADMS IN THE GROUP
GRPCRI IS THE GROUPING CRITERION
GRPBUF IS THE GROUP BUFFER
ROUND UP COMPUTED ARC LENGTH TO NEAREST DEGREE
7
4

Figure 3.1-7(c).

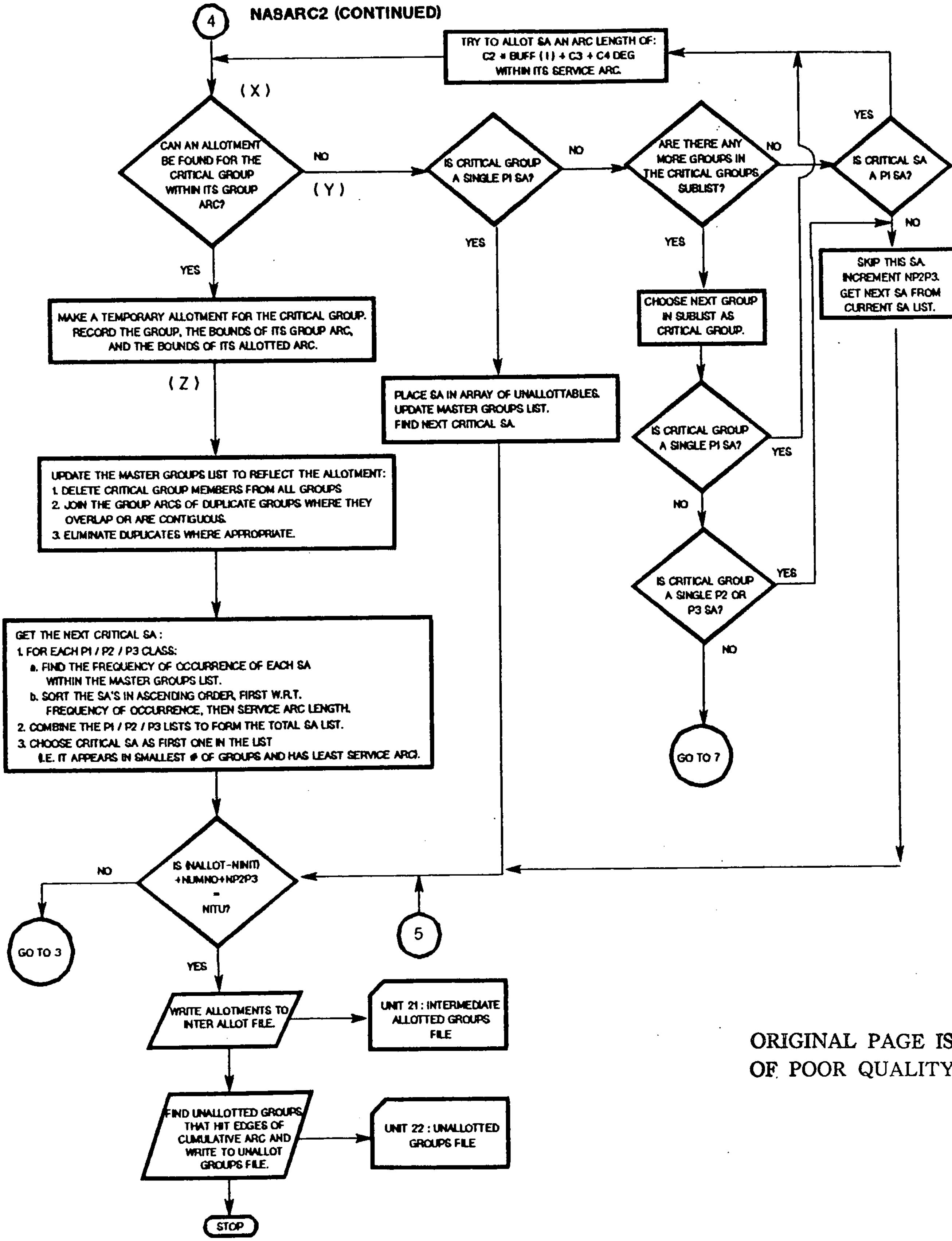


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Figure 3.1-7(d).

ALLOTTED ARC MODULE

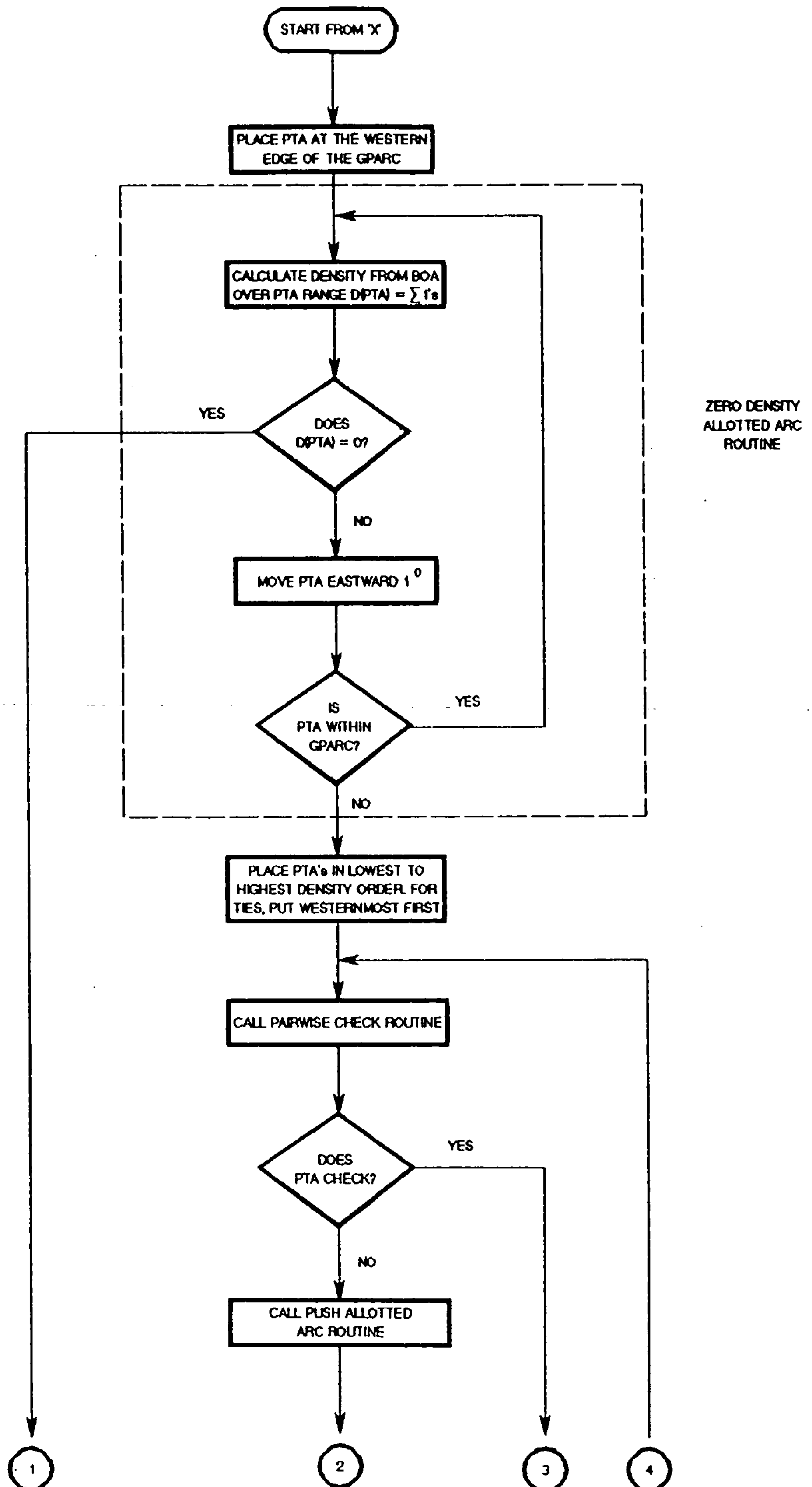
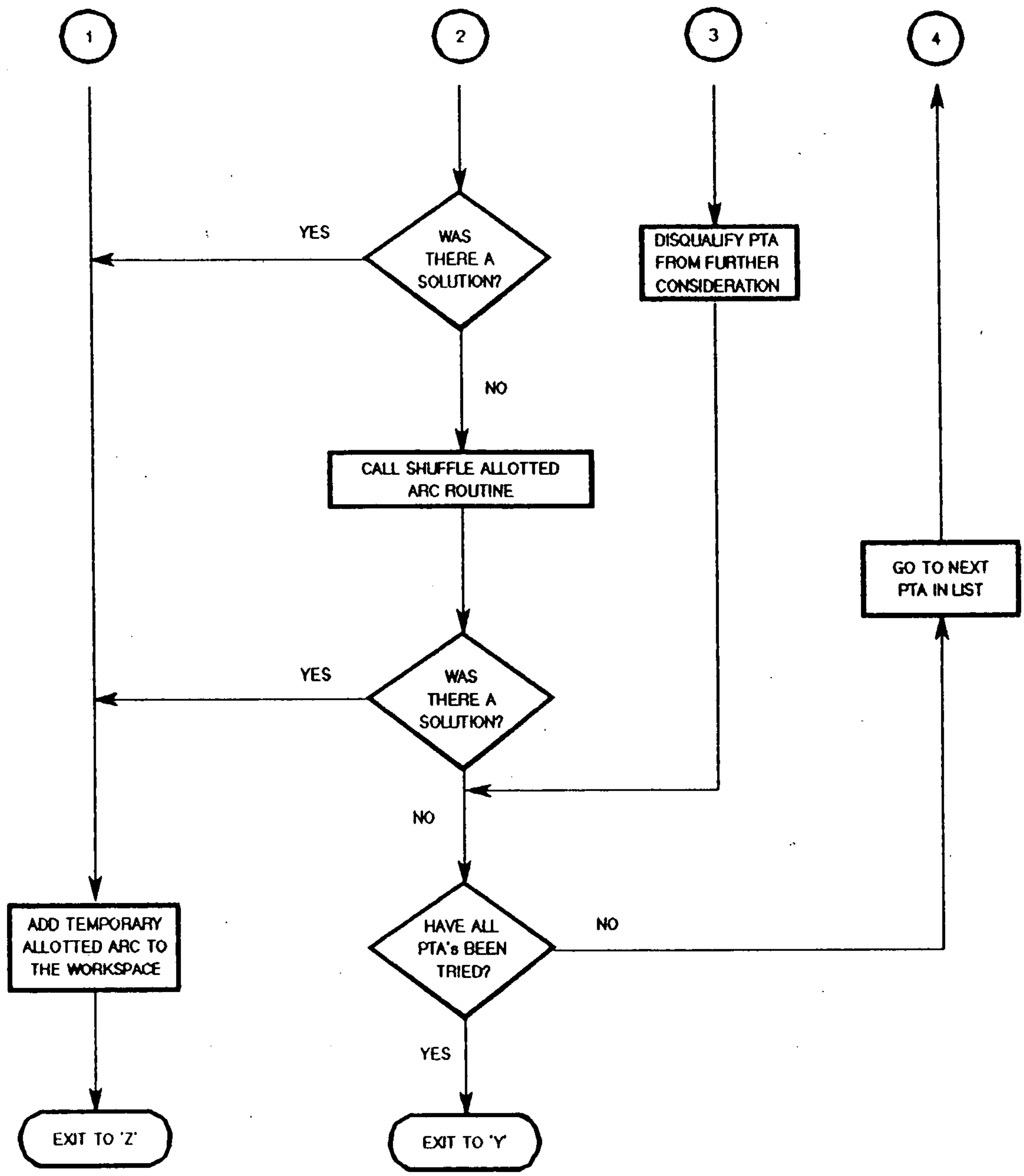


Figure 3.1-8(a).



1
2
3
4
YES
WAS THERE A SOLUTION?
DISQUALIFY PTA FROM FURTHER CONSIDERATION
NO
CALL SHUFFLE ALLOTTED ARC ROUTINE
GO TO NEXT PTA IN LIST
YES
WAS THERE A SOLUTION?
NO
ADD TEMPORARY ALLOTTED ARC TO THE WORKSPACE
HAVE ALL PTA's BEEN TRIED?
NO
YES
EXIT TO 'Z'
EXIT TO 'Y'

Figure 3.1-8(b).

PAIRWISE CHECK ROUTINE

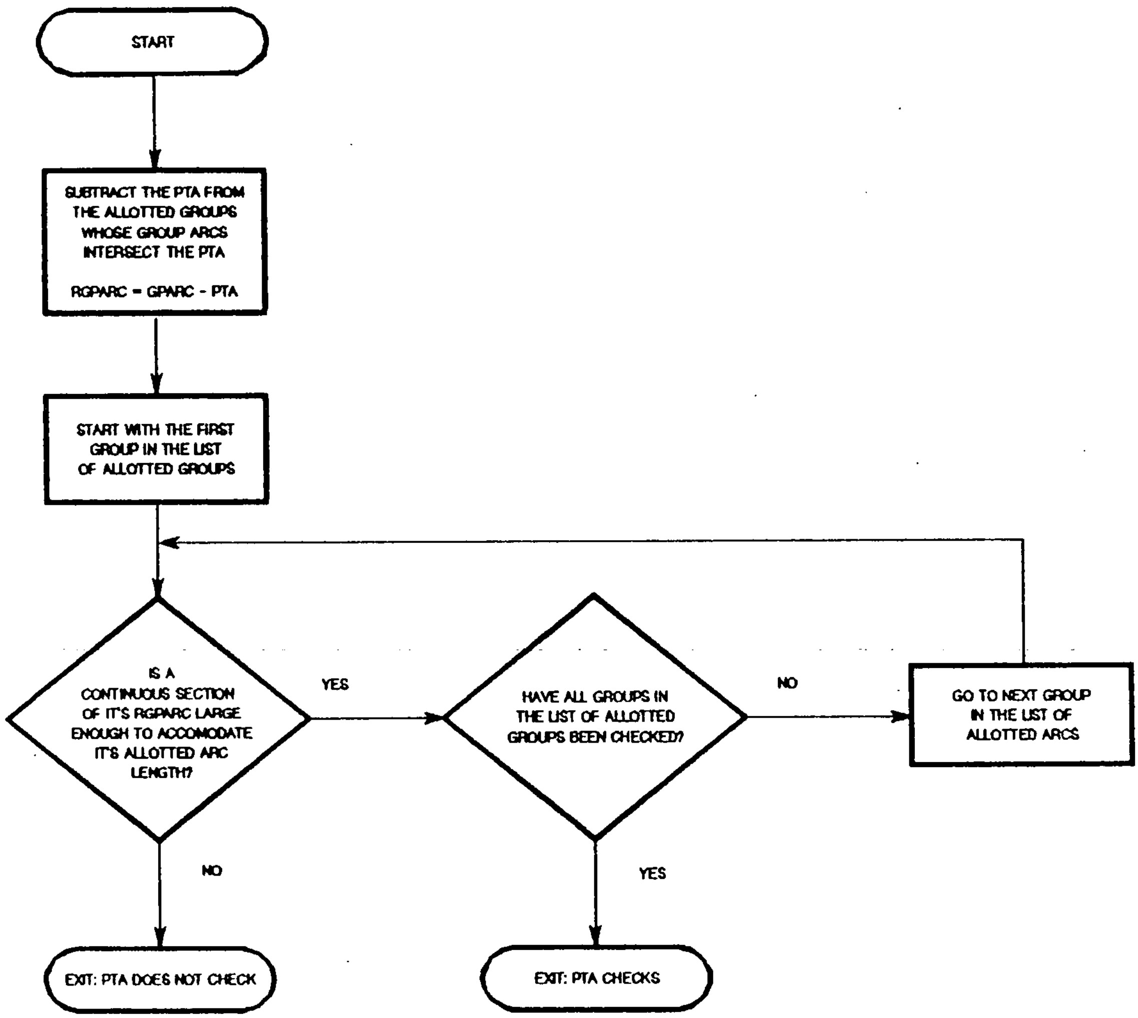


Figure 3.1-9.

PUSH ALLOTTED ARC ROUTINE

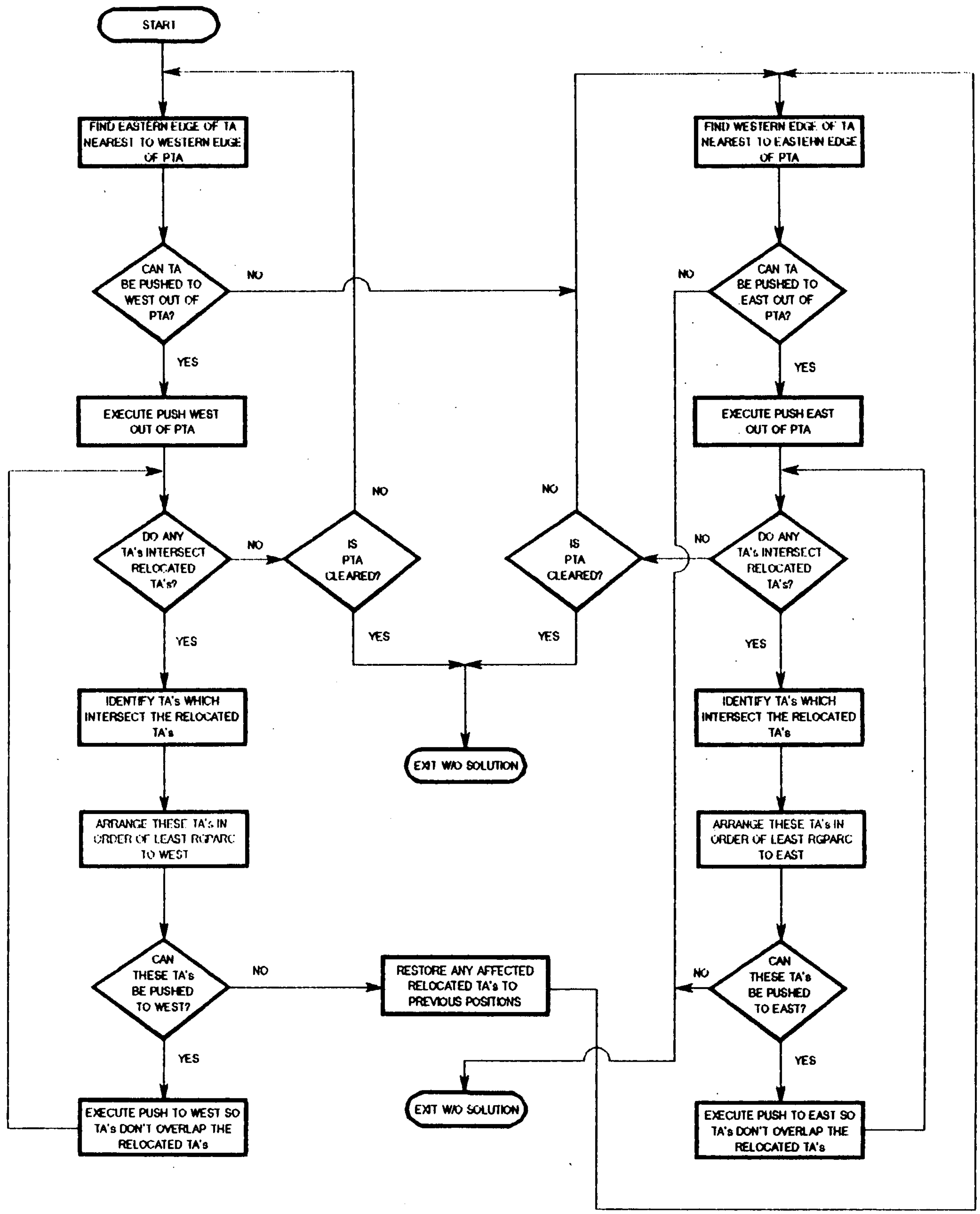


Figure 3.1-10.

SHUFFLE ALLOTTED ARC ROUTINE

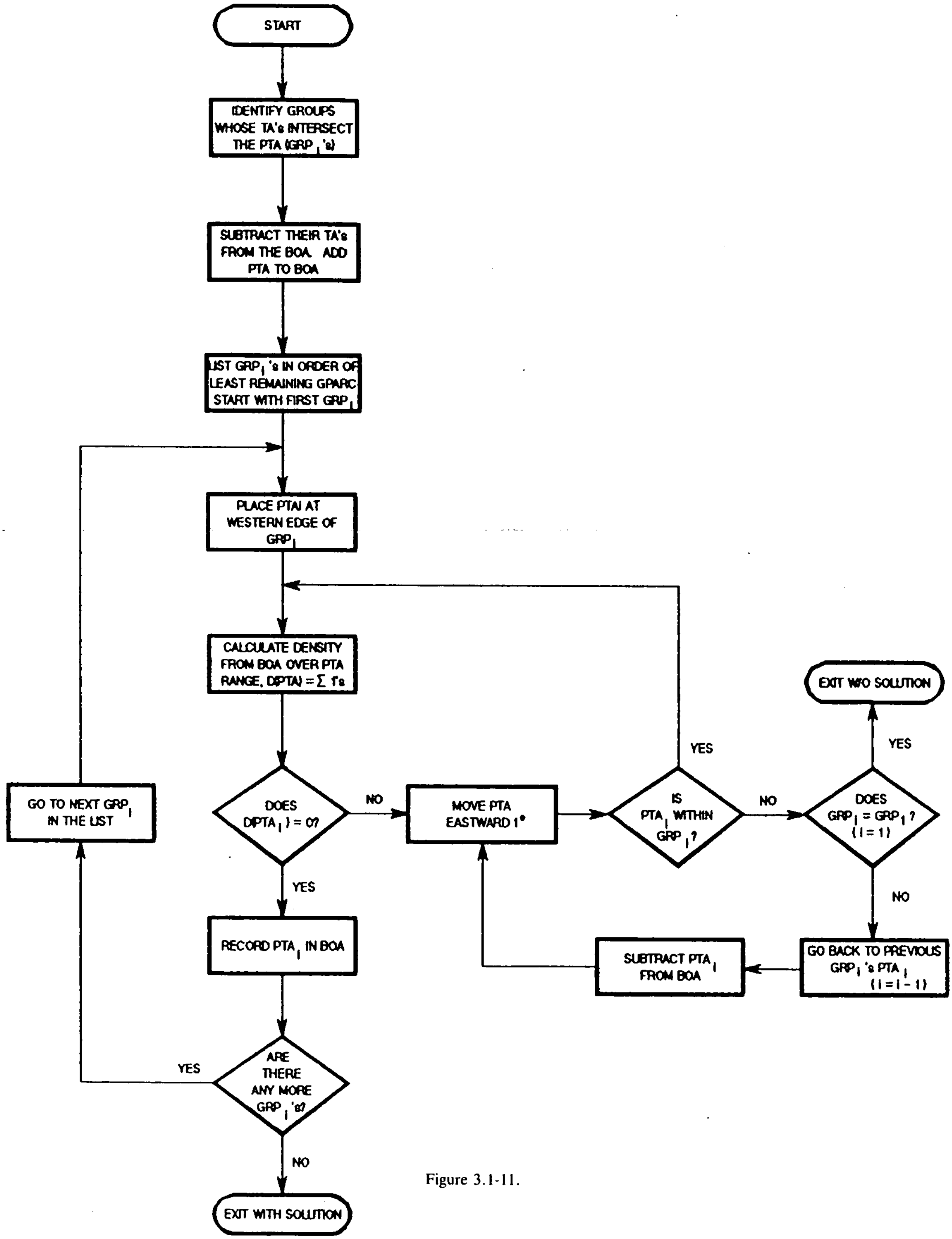


Figure 3.1-11.

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NASARC3 -- The Group Arc Extension Program

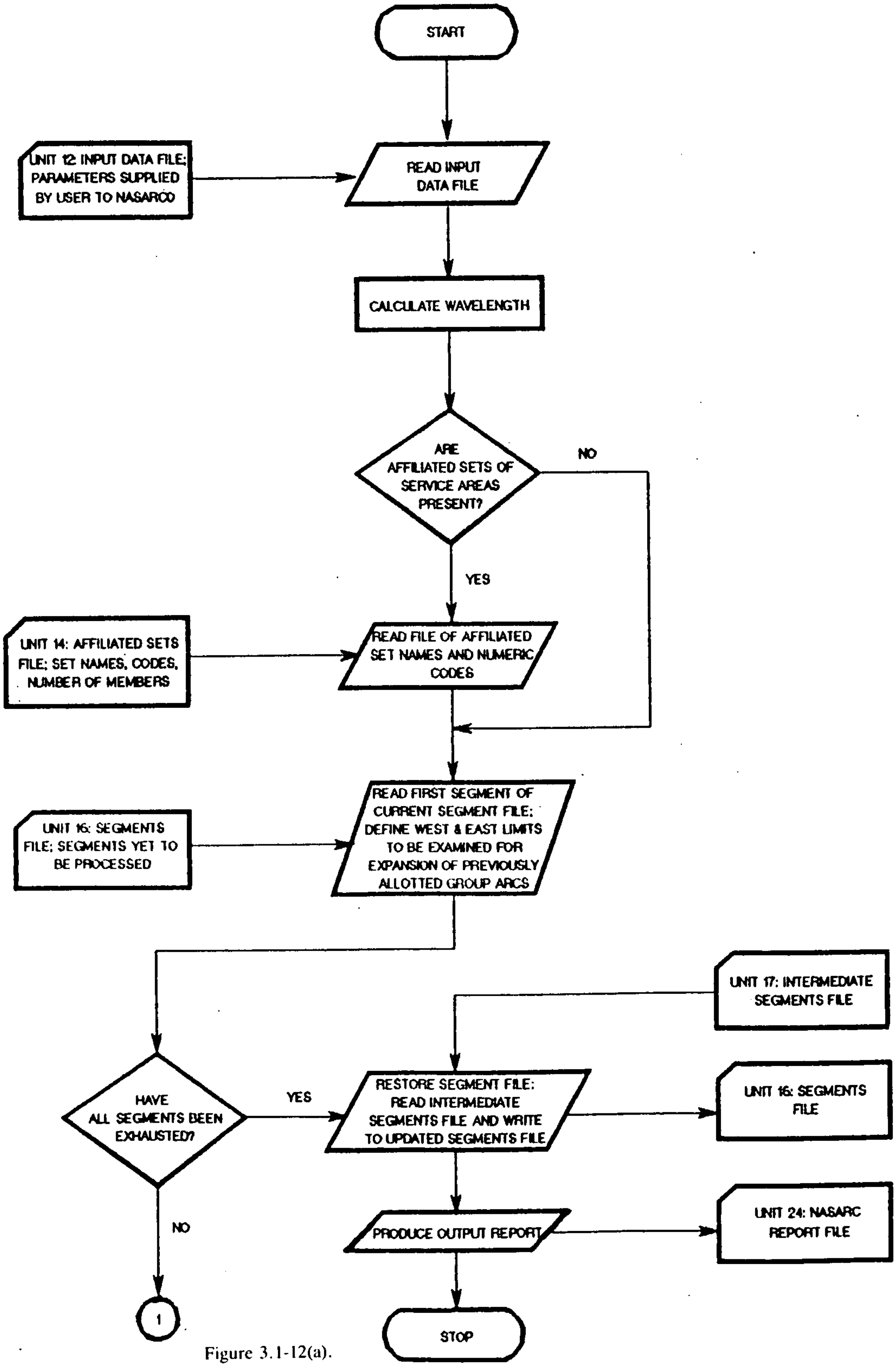

Figure 3.1-12(a).

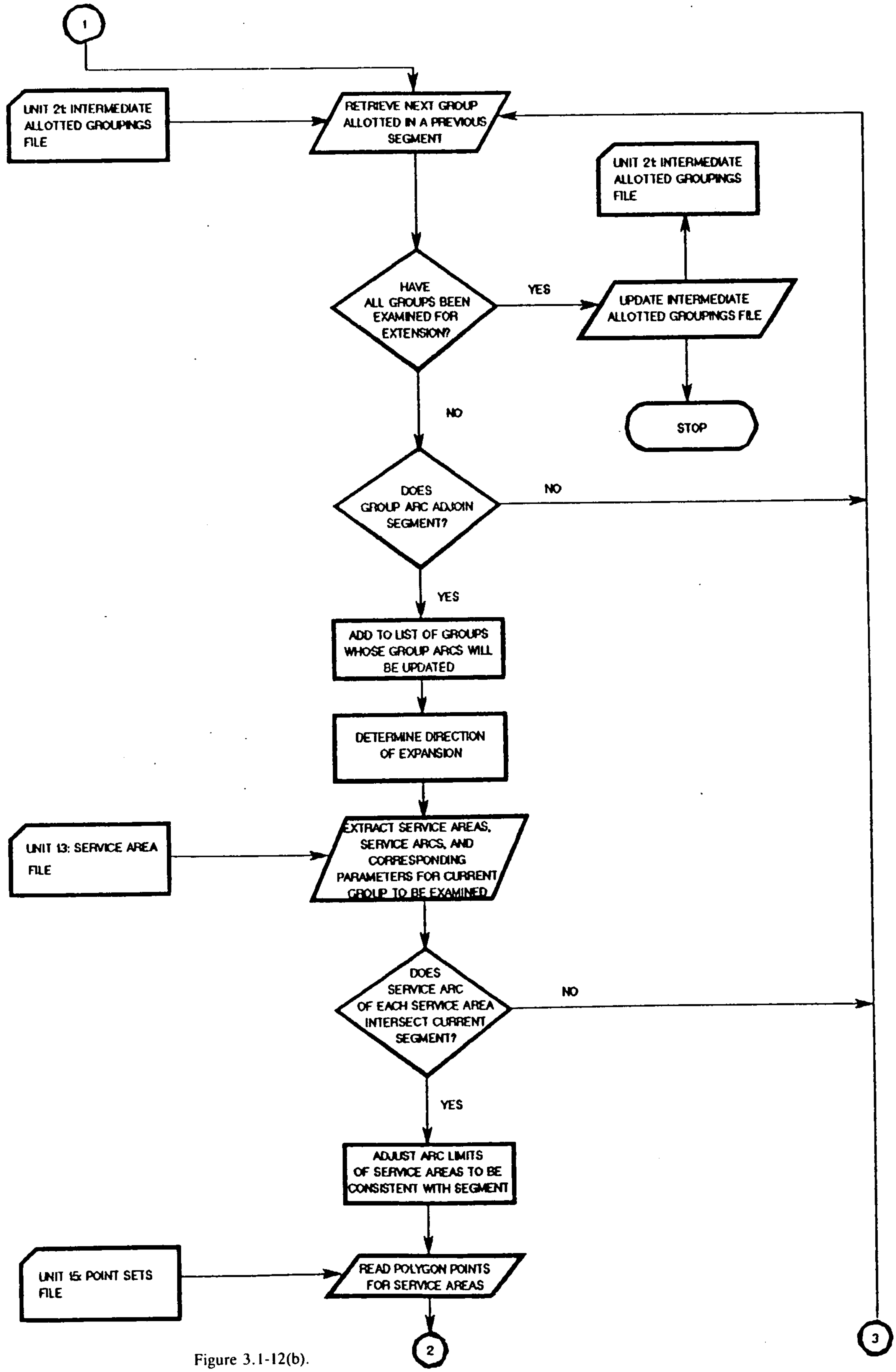

Figure 3.1-12(b).

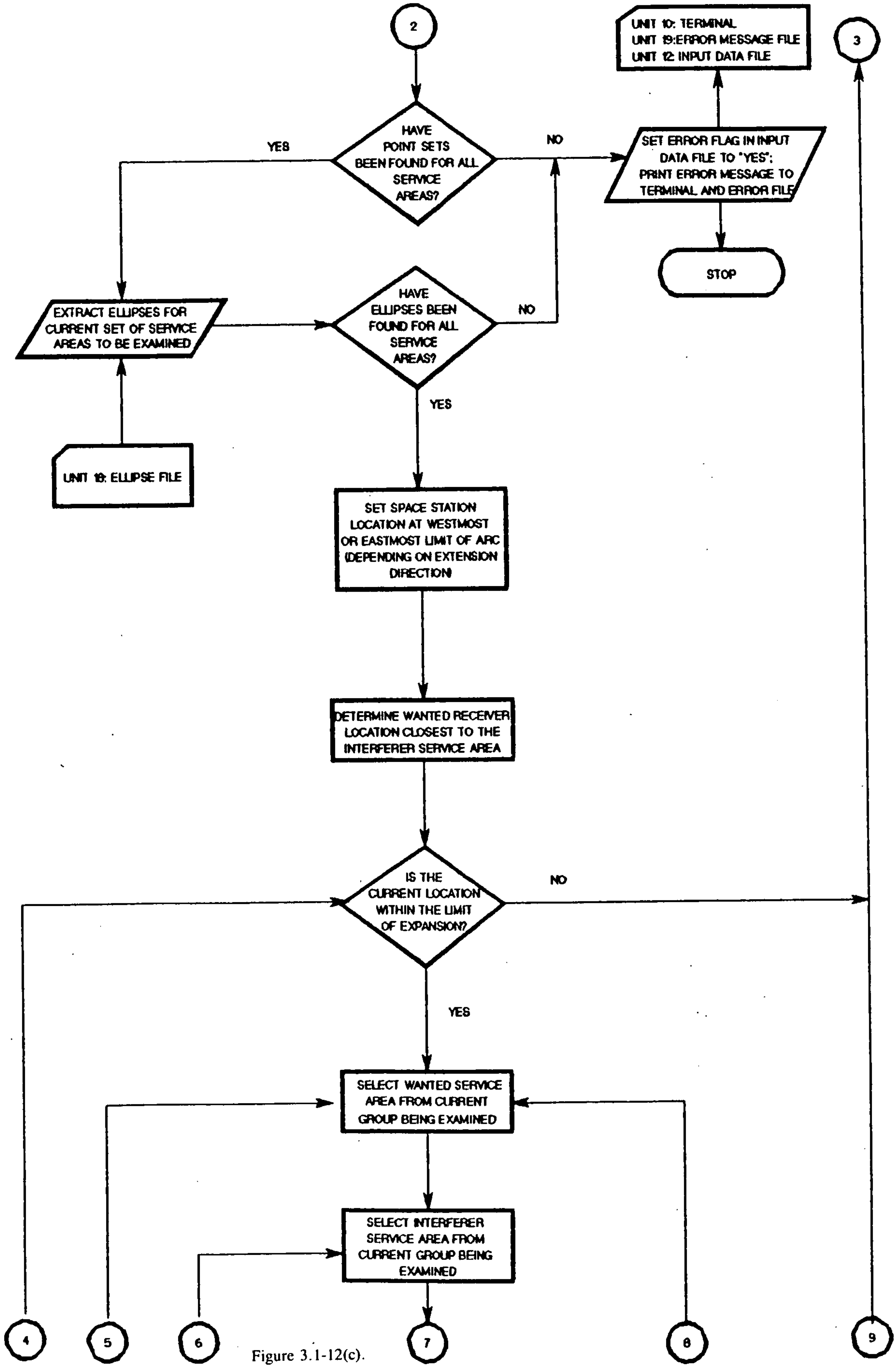

Figure 3.1-12(c).

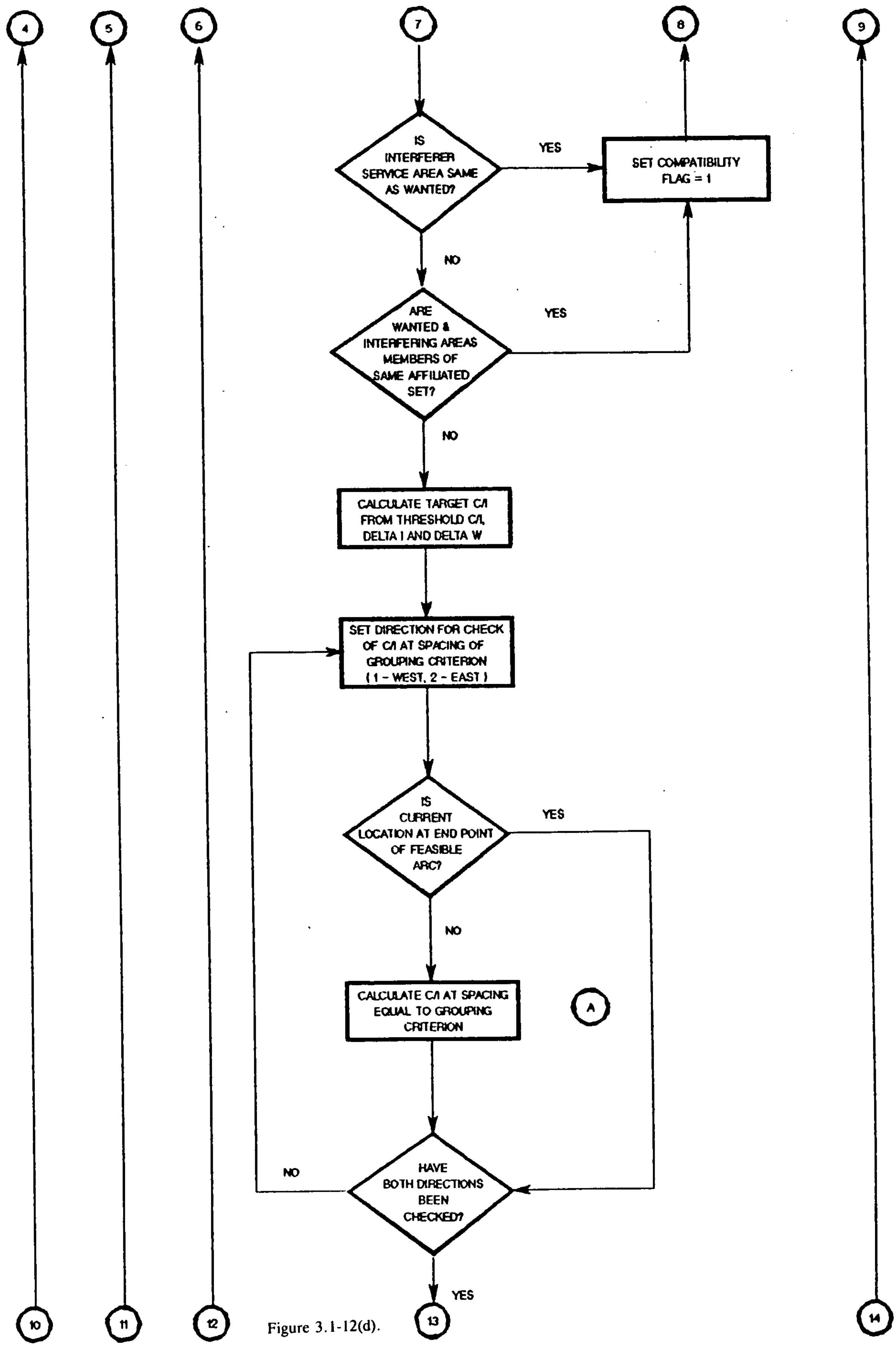

Figure 3.1-12(d).

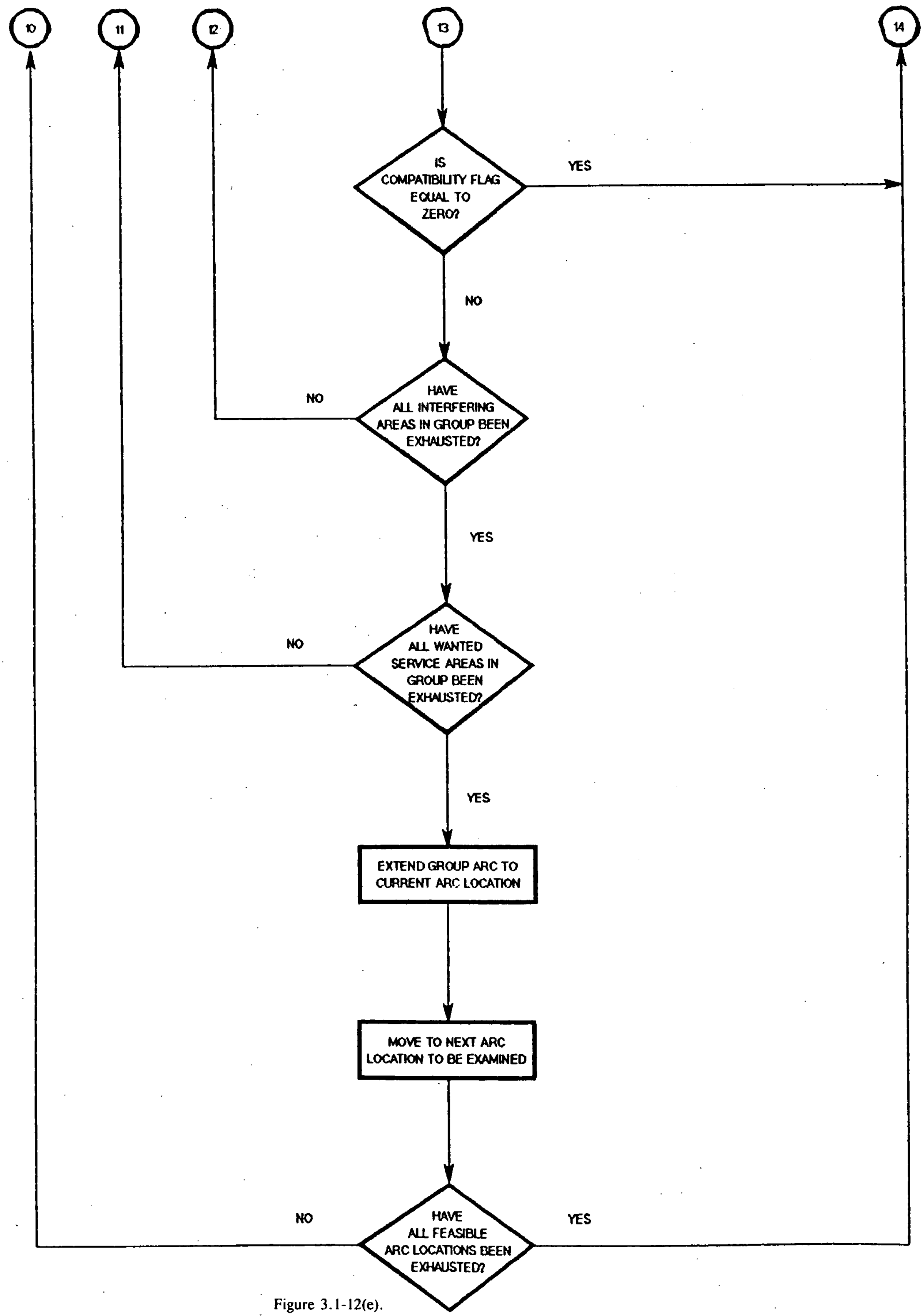

Figure 3.1-12(e).

3.1.1 NASARC0 Module

As stated previously, the NASARC0 module collects data from the user and verifies data present in externally prepared input files to ensure successful execution of NASARC1, NASARC2, and NASARC3 over all portions of the orbit to be examined. (See fig. 3.1-2.)

Input data file verification is performed first. The NASARC0 module first collects constants from the Point Sets file (see section 2.3.1.3) that will be used in the allotted arc length equation within NASARC2. If all four constants are zero, NASARC0 will print an error flag at the top of the Input Data file and will write an appropriate message to the terminal and the Error Message file; otherwise, NASARC0 will proceed. The Segments file is then read by NASARC0; the user will recall from section 2.3.1.1 that the Segments file contains user-specified portions of the orbit to be successively examined by the NASARC1, NASARC2, and NASARC3 modules. NASARC0 verifies that the portions of the orbit specified within the Segments file form a contiguous cumulative arc when joined together. If the specified portions of arc do not form such an arc, the error flag within the Input Data file is appropriately set, and error messages are written to the terminal and the Error Message file. After verification of the Segments file, NASARC0 proceeds to perform several checks on the Service Area file data (see section 2.3.1.2): lengths of service arcs are checked to ensure that they are feasible; service arcs of affiliated service areas are checked to ensure that they intersect; and individually specified antenna characteristics are verified as valid. If any invalid specifications are found, the appropriate error flags and messages are written to the appropriate files. Information gathered from the service area file—such as presence or absence of individually specified antenna characteristics or affiliations between service areas—is used to set appropriate flags within the Input Data file produced by NASARC0. If affiliated sets of service areas are present, NASARC0 reads the Affiliated Sets file (see section 2.3.1.4) and verifies that the appropriate number of member service areas for each set are present within the Service Area file. If the Service Area file and Affiliated Sets file are not in agreement, appropriate error flags and error messages are sent to the appropriate locations. If the two files are in agreement, NASARC0 then verifies that the same set of space station antenna parameters have been specified for all member service areas. (The user will recall that an affiliated set of service areas consists of dispersed service areas that are intended to be served from the same satellite.) If such agreement is not found, the appropriate error messages and flags are produced. If agreement exists, NASARC0 has concluded the file verification portion of its operation. (See figs. 3.1-3(a), (b), and (c)).

Following verification of externally prepared input data files, NASARC0 queries the user for input parameter values to be supplied interactively, such as threshold downlink single-entry C/I, grouping criterion, downlink frequency, minimum ellipse half-power beamwidth, default earth station antenna characteristics, and default space station antenna characteristics (see fig. 3.1-3(c)). Further information on the interactive prompts issued by NASARC0, and expected responses, is presented in section 3.2.5.

Following data collection from the user, NASARC0 calculates a default buffer arc length, based on the earth station antenna characteristics supplied by the user (see fig. 3.1-3(c)).

Prior to conclusion of the NASARC0 program, the user's responses to interactive prompts are written to the terminal; the user is, at this time, afforded the opportunity to alter his or her input values. If any values are altered, the appropriate NASARC0 operations are repeated. When all values are specified to the user's satisfaction, NASARC0 concludes by producing the Input Data file (see section 2.3.1.5) utilized by NASARC1, NASARC2, and NASARC3 (see fig. 3.1-3(d)).

3.1.2 NASARC1 Module

The NASARC1 module, as stated previously, enumerates compatible groupings of service areas and the arc spans over which each such grouping may exist within the portion of the arc currently being examined.

A compatible group of service areas consists of a set of service areas, each of which is compatible with all other members on a pairwise basis. Pairwise compatibility between service areas is assessed on the basis of the satellite separation required to allow systems serving both service areas to meet a target single-entry, downlink *C/I* value. A user-supplied grouping criterion, extracted by the NASARC1 module from the Input Data file, expresses (in degrees of orbital arc) the maximum orbital separation allowable between systems at which the target *C/I* value may be achieved for compatibility. That is, if systems serving two service areas achieve or exceed the target *C/I* value at the grouping criterion spacing, they may be placed closely together in the orbit and are hence compatible.

Over the range of orbital locations currently being examined, assessment of compatibility between all possible pairs of service areas takes place. Groups of systems that may be spaced closely together in orbit (i.e., those that are compatible) are enumerated at each discrete location in the current portion of the orbit. These groups are periodically accumulated into a list of compatible groups and arc spans over which each such group may exist until all possibilities for compatibility in the current portion of the orbit have been exhausted.

The NASARC1 module first collects needed inputs form the Input Data file (see fig. 3.1-4(a)). These inputs will include technical parameter values supplied by the user as well as other data that will affect various operations within the program (see section 2.3.1.5).

The second input file required by the procedure is the Service Area file, which contains a list of service areas, their eastmost and westmost feasible arc locations, and optional data specified for each service area (see section 2.3.1.2). This file will be utilized to establish a preliminary list of service areas to be examined for compatibility within the current portion of the orbit. In addition, the program will set default values (collected from the Input Data file) for optional service area parameters not otherwise individually specified for each service area (see fig. 3.1-4(a)).

If the appropriate flag within the Input Data file indicates that affiliated sets of service areas are to be taken into consideration, NASARC1 will then read the Affiliated Sets file (see section 2.3.1.4). The user will recall that affiliated sets of service areas—geographically dispersed areas that are to be served from a single satellite—will require special handling within NASARC1 (see figs. 3.1-4(a) to (f)).

As described in section 3.1, the NASARC1, NASARC2, and NASARC3 modules will be applied to successive portions of the orbit specified by the user. Thus, any given execution of the NASARC1 module may follow an application of the NASARC1, NASARC2, and NASARC3 modules to a prior portion of the orbit. The user will also recall from section 3.1 that the purpose of the NASARC2 module—the arc determination program—is to select compatible groups of service areas from those found within a portion of the orbit and to determine allotted arcs for the selected groups. Thus, service areas that are included in such groups have already received allotted arcs and do not need to be considered further by the NASARC1 module in subsequent segments of the orbit. For this reason, the NASARC1 module utilizes the Intermediate Allotted Groupings file (see section 2.3.2.3) as input; the service areas that have received allotted arcs are eliminated from the preliminary list of service areas to be considered. If a service area that has received an allotted arc is, in fact, an affiliated *set* of service areas, its member service areas have received allotted arcs and are thus also eliminated from the preliminary list of service areas to be considered within the current portion of the orbit (see figs. 3.1-4(a) and (b)). Such elimination of service areas that need no longer be considered greatly reduces computer time required to analyze all portions of the orbit.

The NASARC1 module must next determine the portion of the orbit to be examined for compatible groups of service areas. The user will recall that the portions of the orbit that are to be analyzed are specified within the Segments file (see section 2.3.1.1). The top record of the Segments file will define the western and eastern arc limits of the current portion of the arc to be examined; when the top record has been read, the remaining records will be read and rewritten to the Segments file; the updated Segments file will thus contain, in its top record, the longitudinal limits of the next portion of the orbit to be examined. The limits of the current portion of the arc to be examined by NASARC1 are also written to the Intermediate Segments file (see section 2.3.2.1), which contains portions of the orbit that have been examined (see fig. 3.1-4(b)).

The service arcs of the service areas contained in the current list are then compared with the current segment to be analyzed by NASARC1; service arc boundaries are adjusted internally—i.e., within NASARC1—to conform to the boundaries of the current segment. If a service area's service arc does not intersect the current segment to be examined, that service area is eliminated from the list of service areas to be considered (see figure 3.1-4(b)). A further check is performed, if applicable, to determine if all affiliated service areas within a set are present within the current segment. The user will recall that affiliated sets of service areas must be treated in an all or nothing manner—that is, all numbers of an affiliated set of service areas must be able to be included in a compatible group or no members must be included. Thus, if the service arc of any member service area of an affiliated set does not intersect the current segment, the remaining member service areas must be eliminated from the list of service areas to be considered (see fig. 3.1-4(c)).

The list of service areas to be considered has now been finalized. Intersections of their modified service arcs (i.e., the segments of service arc that lie within the segment currently being examined) are determined for all pairs of service areas using subroutine INTRST. Sets of polygon points for service areas are extracted from the Points Sets file using subroutines POSPAR and RDPTST; if point sets are not found for all service areas, the error flag within the Input Data file is changed appropriately; error messages are written to the Error Message File and the terminal, and NASARC1 ceases execution (subroutine ERR) (see fig. 3.1-4(c)).

After the extraction of polygon points from the Point Sets file, NASARC1 creates an array of needed ellipse data extracted from the Ellipse file using the CREATE subroutine. Once again, if an error in collecting the needed data is encountered, appropriate flags and messages will be written and the NASARC1 module will stop (subroutine ERR).

The NASARC1 module next determines for each service area the closest polygon point to the center of all other service areas which will be regarded as interferer service areas. This determines worst-case polygon points that will represent the locations of the wanted area receivers in the compatibility assessment for pairs of service areas (see fig. 3.1-4(c)).

Beginning with the westmost possible arc location for any service area, the NASARC1 module calculates a compatibility matrix and enumerates groups of compatible systems for that location. The location is then incremented and the process is repeated until all possible discrete arc locations within the current segment are exhausted. In construction of the compatibility matrix for each location, compatibility assessment for a pair of satellites is not performed unless the current location lies within the intersection of the feasible arcs for both service areas (see figs. 3.1-4(d) to (f)).

At each arc location, calculation of a compatibility matrix takes place. Each entry indicates whether or not a target C/I value is achieved with a specified orbital separation between two satellites, serving a pair of service areas, where the satellite regarded as wanted is represented by the row index and the interfering satellite is represented by the column index. Due to differences in the geographical extent of the service areas corresponding to the satellites (and thus, beam coverage size), the C/I achieved when one satellite is seen as wanted and the other is regarded as an interferer may not be identical to the C/I achieved when the roles of the two satellites are reversed. Thus, the compatibility matrix will initially be nonsymmetric (see fig. 3.1-4(e)). Compatibility is indicated by a one (1); incompatibililty is indicated by a zero (0).

The user will recall that affiliated sets of service areas require special treatment in the determination of compatible groups of service areas. If two service areas are members of the same affiliated set, they will be regarded, automatically, as compatible. However, compatibility between each member service area and all other nonmember service areas will be assessed in the manner to be described.

Calculation of the C/I achieved by each pair of systems at the orbital separation specified by the grouping criterion is performed on the basis of antenna discrimination on the downlink (subroutine CICHK—see fig. 3.1-5(a)). Thus, antenna characteristics are required by the program and are read from the Input Data file and the Service Area file. The characteristics required are those representing the satellite transmit antenna pattern and the earth station receive antenna pattern. As falloff from the on-axis satellite antenna gain is most often

expressed in terms of relative off-axis angle (i.e., the off-axis angle of the satellite antenna divided by the half-power beamwidth in the direction of interest), the half-power beamwidth in the direction of interest must be calculated (subroutine BW). For this reason, a file of ellipses covering the service areas is also utilized by the program. The ellipses needed by the program are extracted from the Ellipse file using the CREATE subroutine. The achieved C/I value is calculated at the given orbital separation between satellites as follows (see figs. 3.1-4(c) to (e)). The current arc location is assumed to be the location of the wanted satellite; what must be determined is whether or not a given orbital separation between this location, and the location of the interferer satellite, will allow the wanted system to meet a target C/I calculated from user inputs. The discrimination of the interferer's spacecraft antenna in the direction of the wanted service area is evaluated using the spacecraft antenna pattern (subroutines SCOFF and DISC). The discrimination of the wanted service area's receive antenna in the direction of the interfering satellite is also evaluated using the earth station antenna pattern (subroutines ESOFF and DISC). The discriminations of the earth station and spacecraft antennas are then added. If the sum is sufficient to meet the required C/I, the needed satellite separation is provided by the grouping criterion, and the two service areas are compatible. If the separation is insufficient to provide the required C/I, the service areas are not compatible. Service areas are also found to be incompatible if the arcs of the service areas in question do not intersect.

When evaluation of the achieved C/I values has been completed at a location, the compatibility matrix for the location is made symmetric, using the results obtained by CICHK. Each entry of the compatibility matrix corresponding to a row and column index is compared to its corresponding entry—that with the row and column indices reversed. If the two entries both indicate compatibility, 1's are present in the corresponding locations of the compatibility matrix. If either or both of the compatibility matrix entries contains a 0, 0's are placed in both corresponding locations of the compatibility matrix.

The compatibility matrix which results thus expresses in 1's and 0's whether any two service areas are compatible at the particular location. The compatibility matrix is now symmetric; symmetry is required for the enumeration of groups of compatible service areas at the current location. Diagonal entries will be set to 1, as each service area is regarded as being compatible with itself (see figs. 3.1-4(d) to (f)). The symmetric compatibility matrix may be regarded as a collection of vectors—one vector for each service area—which expresses compatibility between that service area and all others. A compatible group will consist of a set of service areas whose members are each compatible with all other members. Affiliated sets of service areas will, once again, be treated in all-or-nothing fashion; rows and columns of the compatibility matrix that correspond to single service areas that are members of an affiliated set must be consolidated into a single row and column that expresses the set's compatibilities with other nonmember service areas.

To enumerate groups of compatible service areas, each vector is examined in turn. Each vector will have a 1 in the element corresponding to its own service area index, and additional 1's and 0's indicating compatibilities with other service areas. A complete list of compatible groupings for the current arc location is found by exhaustively examining all possible compatibilities. When a large number of such groups, over several arc locations, have been determined, the groups and arc locations are accumulated into a list of groupings and their associated group arcs over which they have been found (subroutine ACCUM—see fig. 3.1-6). Finally, when all locations have been exhausted, the list of groupings and arc spans is processed one final time in subroutine ACCUM to ensure that the list contains all compatible groupings and the arc spans over which they may exist. This final list is output by subroutine OUTLST to the NASARC1 output file—the Groups file (see section 2.3.2.2) which is utilized by the NASARC2 module as input.

3.1.3 NASARC2 Module

The functions of NASARC2, the arc determination program, are (1) to select appropriate groups of service areas from an exhaustive list of groups generated by NASARC1 for a given portion of the orbit, (2) to determine allotted arc lengths for these selected groups, and (3) to allot each selected group an arc within its group arc that is equal in length to its computed value. What follows is a description of the NASARC2 group selection and arc determination procedures. The reader is referred to the NASARC2 flowcharts in figures 3.1-7 to 3.1-11 throughout this description.

NASARC2 begins by reading in required input data. This is shown in the top portion of figure 3.1-7(a). The program extracts the default buffer length, the grouping criterion, and arc length equation constants from the Input Data file. Orbit segments that have been processed thus far by NASARC1 are read from the Intermediate Segments file. Using the segment information, NASARC2 determines the west and east bounds of the current cumulative arc, the west and east bounds of the current segment, and the direction in which the arc determination procedure will proceed. If the current segment boundaries are east of the previous cumulative arc, the allotted arc buildup will occur west to east. If the current segment boundaries are west of the previous cumulative arc, allotted arc buildup will be east to west. This will prevent large gaps from occurring between adjacent allotted groups. NASARC2 next reads the Groups file, output by NASARC1 for the current segment, to obtain the service areas for the current segment, their service arc longitudes, the service area individual buffer sizes, the compatible groups generated for the current segment, and the group arc longitudes associated with the compatible groups. If the current segment is not the first segment to have been processed, then information related to groups which have been allotted in past segments must also be read, along with any unallotted groups whose group arc adjoins an edge of the current segment (see section 2.3.2.4). The unallotted groups are then appended to the groups list from the Groups file and the group arcs of duplicate groups are combined where appropriate to form a master groups list for the current cumulative arc.

The next step in the NASARC2 procedure involves sorting the service areas into a priority order, checking to see if any are missing from the master groups list, and allotting any missing service areas which are classified as being high-priority service areas. Service areas are partitioned into three classes (designated P1, P2, and P3) according to the amount of contiguous service arc they have outside of the cumulative arc. P1 service areas have the highest priority for inclusion in an allotted group. The amount of service arc they have that extends outside the cumulative arc is no more than an amount equal to their buffer size. Therefore, almost all of their service arc is within the present cumulative arc. It is important that groups which contain P1 service areas be given the first chance of being allotted in the present run, since there is little chance that they will occur in groups generated in subsequent segments. P2 service areas have an amount of service arc outside the cumulative which is greater than their buffer arc size but less than or equal to 20°. They have medium priority. Finally, P3 service areas have more than 20° of service arc outside the cumulative arc. They have a low priority in the current segment, because there is a high probability that they may be accommodated in subsequent segments. After the service areas have been prioritized into P1, P2, and P3 classes, further sorting is done on the service areas within each class. For each class, service areas are sorted in ascending order according to their frequency of occurrence within the master groups list (i.e., the number of groups that the service area appears in). If two service areas have the same frequency of occurrence, then the service area that has the smaller service arc appears first in the list. Thus, in the end, a service area list is created in which the service area at the top of the list is considered to be the critical service area. The service area is critical in the sense that it has the highest priority and appears in the fewest number of groups of any of the service areas represented in the segment. Groups in the master list which contain this service area will be the first ones examined for possible selection. Before collecting these critical groups, however, NASARC2 first checks to see if any of the P1 service areas are missing from the master list (fig. 3.1-7(b)). If a P1 service area is missing, the program computes the arc length requirement using the service area's buffer size, and tries to allot the service area an arc (equal to the computed arc length) within its service arc. If there are missing P2 or P3 service areas, the number missing is simply recorded for later use, but these service areas are not allotted individually.

Once NASARC2 has partitioned the service areas into the allotment priority classes just described and has taken care of any missing service areas, the program enters an iterative loop in which the following steps are performed (figs. 3.1-7(b) to (d)):

(1) Groups containing the current critical service area are compiled from the master groups list.
(2) This sublist of groups is prioritized in order to choose a critical group.
(3) An allotted arc length is computed for the critical group.
(4) NASARC2 tries to allot the critical group an arc span within its group arc that is equal in length to its computed arc length in step (3).
(5) If the group can be allotted, the master groups list is updated to reflect this most recent selection.
(6) The next critical service area is found from the updated master groups list, and the steps are repeated.

Details of the steps in the loop are presented in the following paragraphs.

Step (1) in the iteration involves forming a sublist of groups containing the critical service area from the master groups list. Within this sublist, the group arcs of groups which are subsets of other groups are extended, where possible, in order to work with each group's total available group arc. The arc length requirement is then computed for each group in the sublist, and those groups which fail to meet their arc length requirement are deleted from the list.

In step (2), the sublist groups are prioritized by performing a compound sort on the sublist. The groups are first sorted according to the number of service areas in each group so that the group with the largest number of members is at the top of the list. Then, groups with equal numbers of service areas are sorted so that the group with the largest group arc appears first. Finally, groups with equal group size and equal group arc length are sorted so that the group with the smallest total frequency of occurrence is first. A group's total frequency of occurrence is defined to be the sum of the frequencies of occurrence of its constituent members within the master groups list. Once the sublist has been ordered in this way, the critical group is chosen from the top of the list. The group buffer for this critical group is then determined as the largest individual service area buffer among its member service areas.

In step (3) of the loop, an allotted arc length is computed for the critical group. It is given by

$$AL = C_1 * (N - 1) * GRP + C_2 * GRPBUF + C_3 * N + C_4 \tag{3.1-1}$$

where

AL	allotted arc length, deg
C_1, C_2, C_3, C_4	user specified constants in Point Sets file
N	number of service areas in group
GRP	grouping criterion, deg
$GRPBUF$	group buffer, deg

The result is then rounded up to the nearest degree.

In step (4), NASARC2 tries to allot the critical group an arc span within its group arc that is equal in length to the value computed in step (3). This may involve either trying to find an open spot in the orbital arc somewhere within the critical group's group arc, or, if there are existing allotted groups occupying the critical group's group arc, moving existing allotted arcs in order to open up a space of sufficient length. If an arc allotment can be made, then the critical group is recorded as an allotted group, and its group arc bounds and allotted arc bounds are also recorded.

Execution then continues with step (5). If an allotment of arc cannot be made, then the critical group is checked to see if it is a single P1 service area. If it is, then it is listed as an unallottable service area and execution proceeds with step (5). If it is not, then the next group in the sublist of step (2) is designated as the critical group, and execution proceeds from there. Refer to fig. 3.1-7(d) for more details.

In step (5), the master groups list is updated to reflect the critical group selection by deleting the critical group members from all groups in the master list in which they appear. As a result of these deletions, groups which were previously different from each other may now become duplicates, with their group arcs being adjacent or overlapping in some cases. Hence, it is necessary to examine the list and combine the group arcs of these duplicate groups where they are contiguous or overlapping. Lastly, because selection of the next critical service area is based on frequency of occurrence in the master list, redundant groups must be eliminated from the list in order to maintain the integrity of the selection criterion in choosing the true critical service area.

Step (6) in the iteration involves finding the next critical service area by recomputing the frequency of occurrence of each of the remaining service areas in the updated master groups list. Then, within each of the P1/P2/P3 priority classes, service areas are sorted in ascending order: first with respect to frequency of occurrence, then with respect to service arc length. The separate ordered P1/P2/P3 sublists are then appended to one another to form the complete service areas list. The service area at the top of the list is selected as the next critical service area. Execution then proceeds back to step (1) and the entire process is repeated.

NASARC2 stops executing when all service areas in the present segment are accounted for, when there are no more groups in the master list, or when no remaining arc space is available in the current segment. Before NASARC2 stops, however, it writes all allotted groups to the Intermediate Allotted Groupings file. It also finds the unallotted groups in the master list that adjoin either edge of the cumulative arc and writes them to the Unallotted Groups file. Control then passes to the NASARC3 module.

3.1.4 NASARC3 Module

The NASARC3 module—the group arc extension program—examines groups of service areas that have received allotted arcs through the arc determination process (NASARC2 module) in order to determine if their group arcs may be extended into the next segment of the orbit to be analyzed by NASARC1 and NASARC2. This operation is performed to retain as much flexibility as possible in the arc determination process as applied to all segments of the orbit; that is, should adjustment of prior allotted arcs become necessary in order to accomodate newly allotted arcs, the full group arc will be available for the adjustment.

When a group of compatible service areas has been selected by NASARC2 to receive an allotted arc, the NASARC2 module will examine the arc span over which the group has been found to exist—the group arc—and will select a suitable portion of the group arc to become the group's allotted arc. As stated previously, it may become necessary to revise prior allotted arcs by moving them from their original locations in order to accommodate additional allotted arcs. However, a revised allotted arc for a compatible group of service areas must still lie within that group's group arc. For this reason, the full extent of each group arc into the next segment of the orbit to be analyzed must be determined.

Group arc extension is accomplished by the NASARC3 module in much the same way that group arcs are determined by the NASARC1 module; however, the computational effort required is considerably less. In NASARC1, all possible compatible groups of service areas, and their group arcs, are found within the segment currently being examined; in NASARC3, the group arc that exists for known, previously selected groups of service areas is determined within the segment that is to be analyzed next by NASARC1 and NASARC2. Thus, analysis of compatibility is restricted to a small, known set of service areas.

If no segment of orbit remains to be examined, NASARC3 produces an output file containing all results of the NASARC modules for all segments of the orbit that the user has chosen to analyze—the NASARC Report file (see section 2.3.3.2).

The NASARC3 module first collects needed information from the Input Data file (see section 2.3.1.5); as in NASARC1, various operations of the program will be affected by data within this file—such as treatment of affiliated sets of service areas. If affiliated sets of service areas are to be considered, the Affiliated Sets file (see section 2.3.1.4) is read and processed by NASARC3 (see fig. 3.1-12(a)).

In order to determine both the direction of and limits on the group arc extension to be performed, NASARC3 obtains the next segment to be analyzed from the top record of the Segments file (see section 2.3.1.1). If no segments remain in the file, the NASARC3 module restores the user's original Segments file by copying the Intermediate Segments file (see section 2.3.2.1); the NASARC Report file is then produced by subroutine REPORT (see fig. 3.1-12(a)).

If a segment does remain to be examined, a group of service areas and its group arc are retrieved from the Intermediate Allotted Groupings file (see section 2.3.2.3). The group arc limits are compared with the eastern and western longitudinal limits of the next segment to be examined in order to determine if group arc extension is possible for the group in question. If the eastern limit of the group arc adjoins the western limit of the next segment, group arc extension is a possibility and the extension will be performed in the west to east direction. If the western limit of the group arc adjoins the eastern limit of the next portion of the arc, group arc extension is possible in the east to west direction. If the group arc does not adjoin the next segment to be considered, the NASARC3 module returns to the Intermediate Allotted Groupings file to obtain and check the next group and group arc. When all groups are exhausted, the Intermediate Allotted Groupings file is updated (if necessary) and the program terminates (see fig. 3.1-12(b)).

If group arc extension is possible for a given group of service areas, the NASARC3 module will extract information about the service areas from the Service Area file (see section 2.3.1.2). The service arc of each service area in question must intersect the arc segment to be examined for group arc extension (subroutine INTRST); clearly, if a service area's service arc does not intersect the arc segment, the group arc may not be extended further. If this is the case, the next group and group arc are selected from the Intermediate Allotted Groupings file (see fig. 3.1-12(b)).

If group arc extension is feasible for the group of service areas in question, polygon points for the appropriate service areas are extracted from the Point Sets file (subroutines POSPAR, RDPTST). As in NASARC1, if point sets are not found for all service areas, error flags and error messages are written to the appropriate locations (subroutine ERR), and the program ceases execution. If point set data is collected successfully, ellipse data are then extracted from the Ellipse file (see section 2.3.1.6). Once again, if the data cannot be successfully extracted, subroutine ERR is called and the NASARC3 module stops (see fig. 3.1-12(c)).

The user will recall that the next segment into which the group arc will be extended provides both longitudinal limits of expansion and the direction in which the group arc expansion is to be made. The initial arc location is set to the appropriate western or eastern longitudinal limit of the next segment; this arc location will be incremented if expansion of the group arc is to take place in a west-to-east direction or decremented if expansion is in an east-to-west direction.

Over the portion of arc to be considered, pairwise compatibility between service areas is assessed for each pair of service areas within the current group whose arc is to be extended as in NASARC1 (subroutine CICHK). At each discrete arc location where compatibility between all service areas within the group still holds, the appropriate group arc boundary is adjusted to encompass the new location where the compatible grouping continues to exist. When the group of service areas no longer continues to be compatible, or the next segment has been completely examined for group arc extention, the next compatible group to be examined is taken from the Intermediate Allotted Groupings file (see fig. 3.12(c) to (e)).

When all groups and group arcs in the Intermediate Allotted Groupings file have been examined for extension into the next segment, the Intermediate Allotted Groupings file will be updated to reflect the revised group arcs (see fig. 3.1-12(b)). When this operation has been performed, the NASARC3 module concludes operation.

As stated earlier, if all the segments specified by the user have been examined, the NASARC3 module produces NASARC output results. In order to produce this output, the NASARC3 module must collect information from the Input Data file, the Service Area file, the Affiliated Sets file, and the Intermediate Allotted Groupings file. This information is processed by subroutine REPORT and presented in the NASARC Report file (see section 2.3.3.1).

3.2 Creation of NASARC (Version 2.0) Input Files

In this section details are given on the preparation of data for files input to the NASARC module. The user will recall that detailed discussions of the structures and formats of the Segments file, the Service Area file, the Point Sets file, the Affiliated Sets file, the Input Data file, and the Ellipse file were given in sections 2.3.1.1 to 2.3.1.6; the user is urged to refer to these sections for information on the specific format for the data the user wisher to input. This section is concerned with the derivation of data for input to the NASARC software package and with the transformation of the data into a form compatible with the formats described in section 2.3; the user is also urged to refer to the *NASARC* (*Version* 2.0) *Technical Manual* for conceptual discussion of material presented in this section.

3.2.1 Segments File Data

As was stated in section 2.3.1.1, the NASARC (Version 2.0) software package was designed to apply the NASARC1, NASARC2, and NASARC3 modules, in sequential fashion, to successive portions of the orbital arc defined by the user within the Segments file.

Segments to be examined by NASARC1, NASARC2, and NASARC3 must be specified in the format presented in section 2.3.1.1. The only restriction on the ordering of records within the Segments file is that following the first record all subsequent records must adjoin either the eastern or western boundary of the cumulative arc segment defined by preceding records. A segment adjoins a prior segment if the western and eastern arc limits or eastern and western arc limits, respectively, differ by exactly 1°. As may be inferred from the preceding statement, no two segments specified within the Segments file may overlap—that is, encompass any of the same orbital locations.

The segments to be examined by the NASARC1, NASARC2, and NASARC3 modules are defined by longitudinal limits expressed in decimal degrees. In each record, the western longitudinal limit of the segment to be examined must be followed by the eastern longitudinal limit. Such longitudes must be in the range (−179.00, 180.00); should a segment cross the 180° meridian, the western longitudinal limit will be numerically greater than the eastern longitudinal limit. Thus, it is possible that a segment will be described within the Segments file with a positive (greater than or equal to 0.0) western limit and a negative eastern limit. It is also possible (if a large portion of the orbit is used) that both limits will be negative but that the western limit will be less negative than the eastern limit.

While all sets of segments specified according to the previous guidelines are valid, the most effective and efficient use of the NASARC (Version 2.0) software package is achieved if the segments to be analyzed are selected in a strategic manner. The primary goal of the piecewise approach to allotting orbital arcs is to reduce memory requirements and run time needed for execution of the overall software package while obtaining useful allotted arcs for all service areas considered. This goal may be achieved by attempting to equalize the number of service areas to be considered within each segment of the orbital arc.

Figure 3.2-1 presents a graph of the number of service areas whose service arcs encompass an orbital location (longitude) versus orbital location (longitude). From the figure, we see that there is a portion of the orbital arc—extending from approximately −10° east longitude to 40° east longitude—that contains the area of peak density of service arcs for service areas. However, many service areas whose service arcs intersect the peak-density portion of the orbit have service arcs that include significant portions of arc that fall outside the peak-density segment. If allotted arcs can be obtained for these service areas in portions of the orbit outside the peak-density area, the number of service areas that must be considered for the peak-density portion of the orbit can be reduced—requiring less computer time and memory for use of the NASARC modules on this portion of the orbit.

After consideration of the previous discussion, it should be clear to the user that it is desirable to begin use of the software package in a low-density portion of the orbital arc. It is not necessarily more advantageous, however, to begin with the portion of the orbit which encompasses the *lowest* density of service arcs. The user

SERVICE ARC DENSITY

WORLD ARCS FILE

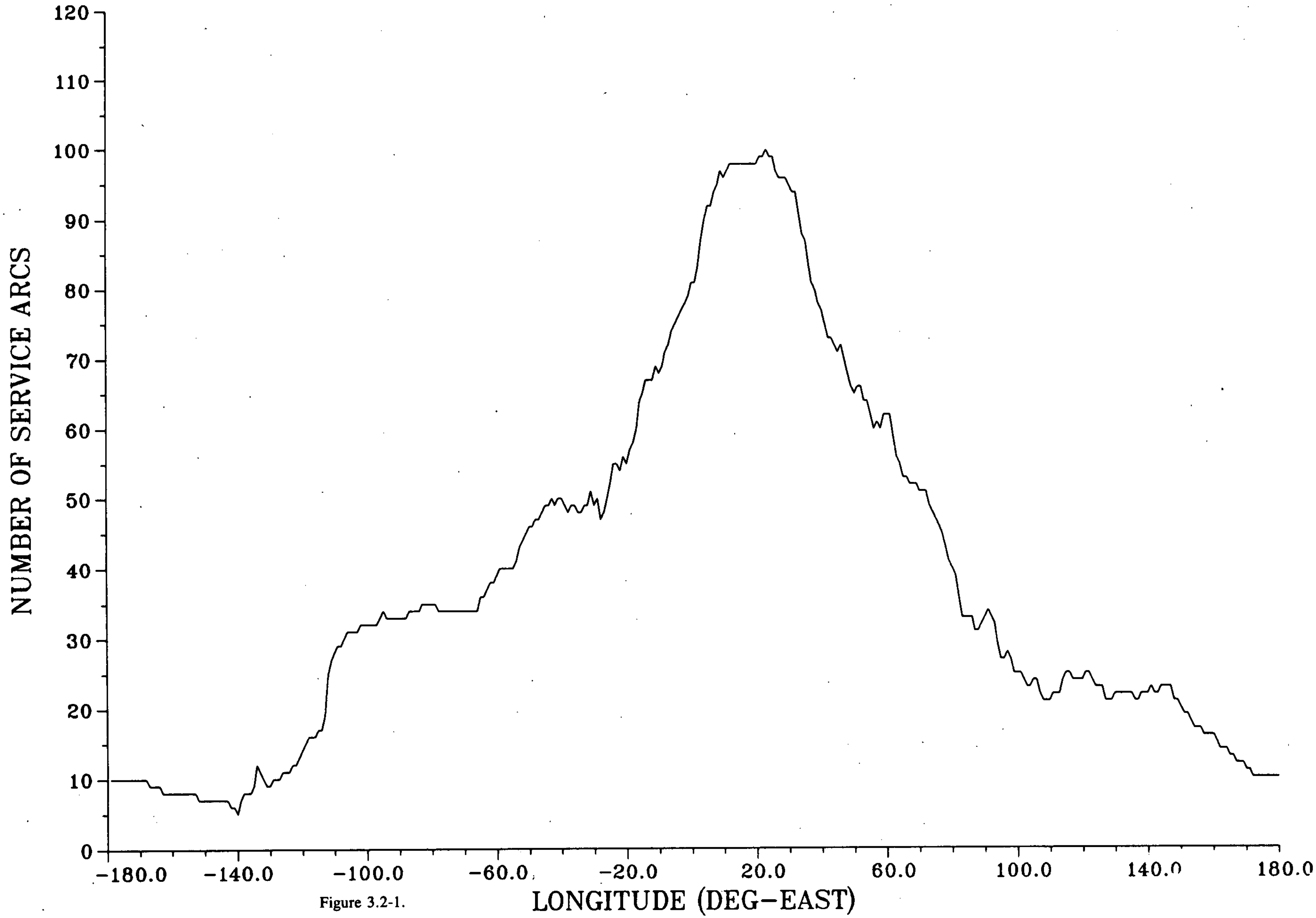

Figure 3.2-1.

must keep in mind that the goal is to equalize the number of service areas examined within each segment of the arc. Thus, the most effective approach may be to begin with a portion of the orbit to the east or west of the peak area and progress through areas of lower density using larger segment of arc until all the segments that the user wishes to examine have been considered. Alternatively, the user might choose a large segment of arc encompassing low-density areas of the curve and alternate segments of arc to the east or west of the original segment in approaching the peak-density portion of the orbit. It is difficult to quantify a precise recipe for selecting the segments to be analyzed and the order in which to analyze them; the user will quickly learn from his own experience which approaches are suited to particular sets of circumstances.

An example Segments file is presented in figure 3.2-2; the example file may help to illustrate the discussion presented in this section.

```
FILE: WORLD10  SEGMNTS  A

   106.00   150.00
    86.00   105.00
   151.00  -115.00
  -114.00   -70.00
   -69.00   -45.00
   -44.00   -30.00
    71.00    85.00
   -29.00   -10.00
    -9.00    70.00
```

Figure 3.2-2.

3.2.2 Service Area Data

Data contained in the Service Area file, as discussed in section 2.3.1.2, has a variety of functions. First and foremost, the data contained in the Service Area file establishes a complete list of service areas to be examined for arc determination within the segments defined by the user along with service arc limits for each area. Each record of the file may also contain optional data that may be applied to the individual service area in question. The required and optional inputs are described in subsequent sections; details of their format appear in section 2.3.1.2.

3.2.2.1 Service Area/Service Arc Data

As stated in section 2.3.1.2, the Service Area file utilized by NASARC modules contains a list of service areas and the western and eastern longitudinal limits of the service arc associated with each. Each service area is symbolized by a three-character service area code. It is most convenient to use the designations utilized by the International Telecommunication Union; however, any ITU designation containing less than three characters must be padded with 0's for proper processing by the NASARC modules. Western and eastern limits of each service area's associated arc are expressed in integral decimal degrees of east longitude, ranging from $-179.00°$ to $180.00°$. These limits correspond to the limits of a service area's service arc for the elevation angle desired by the user. However, it must

be remembered that high-latitude service areas may have narrow or nonexistent service arcs for high elevation angles. It is suggested that in such cases, the user choose, the elevation angle that produces a service arc length of at least 30° when available. This will greatly increase the likelihood of finding compatible groups containing the service area in question and of allotting an arc to that service area. For precise detail of a suggested service arc determination method the user is referred to section 3.1.1.2 of the *NASARC (Version 2.0) Technical Manual.*

Within the Service Area file, records for service areas must be placed in alphabetical order. This ordering should be performed by the user in constructing the file and is necessary to maintain consistency with the Ellipse file furnished with the NASARC (Version 2.0) software package.

3.2.2.2 Optional Service Area Data

As discussed in section 2.3.1.2, specification of optional service area data will depend on the complexity of the situation the user wishes to examine with the NASARC (Version 2.0) software package; the options have a variety of purposes described in the following sections. The user is also referred to the *NASARC (Version 2.0) Technical Manual* for detailed discussion related to these optional inputs; optional data items are described in subsequent sections in the order in which they appear following the required data entries described in section 3.2.2.1.

3.2.2.2.1 Set Affiliation Code Data

The set affiliation code is an integer which indicates that a service area is to be included in an affiliated set of service areas. The user will recall that an affiliated set of service areas consists of geographically dispersed areas that are to be served from a single satellite. By placing the same numeric code in the records of several service areas, the user indicates that the service areas are all members of the same set. Service areas with nonidentical codes are not considered to be members of the same set. If no code is specified, or the code specified is equal to zero, the service area is regarded as independent—that is, not a member of any set.

Integer codes utilized to express set affiliation must correspond with numeric codes in the Affiliated Sets file—that is, no code (other than zero or blank) should appear in the Service Area file unless that code also appears in the Affiliated Sets file. Codes utilized in both files should follow the sequence 1, 2, ..., etc.; that is, 3 should not be utilized as a set affiliation code unless 1 and 2 have already been utilized to designate other affiliated set members.

Finally, the number of service area records containing a particular set affiliation code should correspond to the number of members identified for the appropriate affiliated set in the Affiliated Sets file.

For further discussion of the concept of affiliated sets the user is referred to the *NASARC (Version 2.0) Technical Manual.*

3.2.2.2.2 Inhomogeneity Factor Data

The inhomogeneity factor, expressed in decibels, allows the user to take into account a variety of inhomogeneities between service areas when assessing their compatibility—such as differing satellite power levels or rain attenuation.

The inhomogeneity factor is taken into account in the calculation of the target C/I value that must be achieved or exceeded for the wanted service area at the orbital separation between wanted and interfering satellites given by the user-supplied grouping criterion. The target C/I value is calculated as follows:

$$C/I_{\text{Target}} = C/I_{\text{Threshold}} + \Delta_w - \Delta_i \tag{3.2-1}$$

where

$C/I_{\text{Threshold}}$	C/I value supplied by user to NASARC0 program, dB
Δ_w	inhomogeneity factor for wanted service area, dB
Δ_i	inhomogeneity factor for interferer service area, dB

A detailed discussion of the use of the optional inhomogeneity factor will not be offered here; rather, the user is strongly urged to refer to section 3.1.1.2.3 of the *NASARC (Version 2.0) Technical Manual* for a full discussion of the inhomogeneity factor and its use.

The user should be aware that if the inhomogeneity factor is not specified for any service area, calculations within the NASARC modules will take place using the assumption of clear-sky conditions and constant power flux density at the edge of the minimum area ellipses covering service areas.

3.2.2.2.3 Antenna Characteristic Data

Section 2.3.1.2 stated that space station antenna characteristics may be specified individually for each service area. These characteristics are described by three inputs—the space station antenna pattern code, the space station antenna parameter, and the space station antenna efficiency; the value and type of space station antenna parameter required will depend upon the antenna pattern selected by the user. The format for specification of these items is given in section 2.3.1.2.

Should the user not wish to select a space station antenna for an individual service area, the NASARC programs will utilize the space station antenna pattern code specified by the user to the NASARC0 program. The user may wish to utilize this default pattern but may also wish to specify a different parameter value suitable for a particular service area. This is acceptable, provided that care be taken to ensure that the type and value of the space station antenna parameter specified are consistent with the default pattern type selected by the user. Finally, the user may wish to specify an antenna efficiency value for a particular service area that differs from that specified for other service areas. This is also acceptable. Where individual values are not specified for service areas, default values supplied by the user to the NASARC0 program will be used.

Similarly, earth station antenna characteristics may be specified individually for each service area. Earth station antenna characteristics are also described by three inputs—in this case the earth station antenna pattern code, the earth station diameter (expressed in meters), and the earth station antenna efficiency. The format for specification of these items is given in section 2.3.1.2.

Should the user not wish to select an earth station antenna pattern for an individual service area, the NASARC programs will utilize the earth station antenna pattern code supplied by the user to the NASARC0 module. Alternatively, the user may wish to utilize this default pattern, but wish to specify an earth station antenna diameter suitable for a particular service area. Finally, the user may wish to specify an antenna efficiency value for a service area that differs from that specified for other service areas. All of these options are acceptable. Where individual values are not specified for service areas, the default value supplied by the user to the NASARC0 program will be used.

Antenna efficiencies are always expressed as decimal percentages—that is, 55-percent efficiency is expressed as 0.55. Thus, any antenna efficiency specified must be greater than or equal to 0.0 and less than or equal to 1.0. Antenna efficiency for space station and earth station antennas is expressed in this manner regardless of the antenna pattern type and antenna parameter value otherwise specified.

The user may select a space station antenna pattern type from a collection of patterns implemented within the NASARC programs; once a six-character pattern code has been selected, the user need specify at most one additional space station antenna parameter value in order to fully describe the desired antennas.

The nine types of space station antennas available in the NASARC (Version 2.0) Software package, and their associated six-character codes, are as follows:

SCA558 Satellite antenna pattern presented in CCIR Report 558-3

RARCST Standard rolloff satellite antenna pattern given in the RARC-83 Final Acts

RARCFR Fast rolloff satellite antenna pattern given in the RARC-83 Final Acts

FASTRO Improved fast rolloff satellite antenna pattern presented in Document No. AH-178-296 of the IRAC

ORBIT0 Satellite antenna pattern utilized in the ORBIT-II synthesis program by KDD of Japan

ORBITF ORBIT-II satellite antenna pattern with a -10 dB floor added for use in NASARC

WARC77 Satellite antenna pattern given in the WARC-77 Final Acts

IWP4/1 Fast rolloff satellite antenna pattern presented in CCIR Report 558-3 and recommended by IPW4/1 (June 1986)

IWPIMP Fast rolloff satellite antenna pattern recommended by IWP4/1 (May 1987)

The user may select from two earth station antenna patterns implemented within the NASARC (Version 2.0) software. The two patterns available are the following:

ETA391 Earth station antenna pattern presented in CCIR Report 391-4 with 32-25 log (φ) characteristic

ETAIMP Earth station antenna pattern presented in CCIR Report 391-4 with 29-25 log (φ) characteristic

The associated input parameters related to each of the antenna patterns are given in table 3.2-1; the corresponding falloff equations are given in the *NASARC* (*Version* 2.0) *Technical Manual* in sections 3.1.2.3.1 through 3.1.2.3.11.

TABLE 3.2-1—ANTENNA PATTERNS AND ASSOCIATED INPUT PARAMETERS

Antenna code	Associated input parameter	Typical range of values	*Technical Manual* reference section
ETA391	Antenna diameter	3.0-10.0 m	3.1.2.3.1
ETAIMP	Antenna diameter	3.0-10.0 m	3.1.2.3.2
SCA558	Falloff to first sidelobe level	20.0-30.0 dB	3.1.2.3.3
RARCST	None required	-------	3.1.2.3.4
RARCFR	None required	-------	3.1.2.3.5
FASTRO	None required	-------	3.1.2.3.6
ORBIT0	Decay constant, α	3.5-5.5	3.1.2.3.7
ORBITF	Decay constant, α	3.5-5.5	3.1.2.3.8
WARC77	None required	-------	3.1.2.3.9
IWP4/1	Falloff to first sidelobe level	20.0-30.0 dB	3.1.2.3.10
IWPIMP	Focal length-to-diameter ratio	1.5-4.5	3.1.2.3.11

3.2.3 Point Sets File Data

As stated in section 2.3.1.3, the Point Sets file – as furnished with the NASARC (Version 2.0) software package—contains two types of data.

The first block of data appearing in the file contains values for a series of four constants used in the calculation of the allotted arc lengths to be given to compatible groups of service areas by the NASARC2 module. The precise usage of these constants is described subsequently and in the *NASARC (Version 2.0) Technical Manual* in section 3.3.4.2.

Following the constant values described previously, the Point Sets file contains sets of polygon points for 222 service areas. This portion of the file should not require modification by the user; however, construction of this type of data is described in section 3.2.3.2 in the event that user modification of point set data becomes necessary.

Precise format requirements for both types of data are given in section 2.3.1.3.

3.2.3.1 Constants for Allotted Arc Equation

The four constants contained within the Point Sets file are used to calculate the length of the allotted arc to be given to a particular group of compatible service areas. The allotted arc length is determined in the NASARC2 module as follows:

$$AL = C_1 * (n - 1) * GRP + C_2 * GRPBUF + C_3 * N + C_4 \qquad (3.2\text{-}2)$$

where

C_1, C_2, C_3, C_4	constants specified within Point Sets file
AL	allotted arc length
N	number of compatible service areas contained in group
GRP	user-supplied grouping criterion, deg
GRPBUF	calculated group buffer arc length, deg (see *NASARC Technical Manual*)

Equation (3.2-2) shows that it is not desirable to set all constants C_1, C_2, C_3, and C_4 equal to zero as this would result in an allotted arc length of 0°. For this reason, an error message is generated by the NASARC0 module during verification of user input files if the situation $C_1 = C_2 = C_3 = C_4 = 0.0$ exists within the Point Sets file.

The user will observe that equation (3.2-2) allows for weighting of factors to be taken into account in the calculation of allotted arc length. For instance, the user might have selected 0.0° (colocation) for the value of the grouping criterion *GRP*. In this situation, the user would be well advised to include provision in the equation to adjust the value of the allotted arc length for the number of compatible service areas involved. Thus, the user would wish to provide a nonzero value for the constant C_3. A variety of other situations may be taken into account in a similar manner.

The user is strongly advised to consult the *NASARC (Version 2.0) Technical Manual* (section 3.3.4.2) before experimenting with values for C_1, C_2, C_3, and C_4 that differ from the values provided in the Point Sets file furnished with the NASARC (Version 2.0) software package.

3.2.3.2 Point Set Data

In order for the NASARC modules to run successfully, the Point Sets file must contain (at minimum) a set of polygon points for each service area included in the Service Area file. Up to ten such points may be specified for each service area; the points should define a convex polygon of latitude-longitude pairs that closely approximates

the geographical boundary of the service area. Generally, a good representation may be obtained with fewer than ten points. For consistency, when the ORBIT-II model is to be used in conjunction with NASARC, six or fewer points should be used. In the Point Sets file furnished with the NASARC (Version 2.0) software package, six or fewer points have been utilized to describe each of 222 service areas. The data that the user must provide, if constructing a point set for a given service area, are listed and described in table 2.2-3.

3.2.4 Affiliated Sets Data

The Affiliated Sets file, described in section 2.3.1.4, contains an integer numeric code, a three-character code, and the number of member service areas for each affiliated set of service areas to be examined by the NASARC modules. The user will recall that an affiliated set of service areas consists of a collection of geographically dispersed service areas that are to be served from a single spacecraft.

Each item of data furnished for each affiliated set of service areas has a specific purpose. The user will recall from the discussion presented in section 3.2.2.2.1 that each service area within the Service Area file may be assigned an integer numeric code indicating membership in an affiliated set of service areas. The integer numeric code provided for each affiliated set within the affiliated sets file provides a link between each affiliated set and its member service areas; thus, the numeric code supplied for each affiliated set within the Affiliated Sets file must match the numeric code in number of records of member service areas within the Service Area file. Codes utilized should follow the sequence 1, 2, ..., etc.; that is, the first affiliated set represented within the Affiliated Sets file should have numeric code 1; the second, 2; and so on. Service Area file records for service areas that are members of the set with code 1 should all contain a 1 in the affiliation code field.

Each affiliated set's numeric code is followed by a three-character set code. The user will recall from previous discussions within this manual that affiliated sets of service areas must be treated in an all-or-nothing manner within the NASARC modules. As an affiliated set is a set of geographically separated service areas that are to be served from a single satellite, affiliated set members may only be placed in a larger compatible group of service areas if all set members are eligible for inclusion. Service area codes for individual member service areas will not appear in any compatible groups of service areas generated by NASARC1. Rather, if and only if all member service areas of an affiliated set may be included in a compatible group of service areas, the three character set code will take the place of individual three-character codes for member service areas. In this way, it is ensured that all members of an affiliated set of service areas will be treated as a single entity in the arc determination process, as desired. The choice of a three-character set code is left to the user; however, care should be taken to avoid accidental duplication of any administration code.

The final item to be included for each affiliated set in the Affiliated Sets file is an integer, expressing the number of members in each affiliated set of service areas. This item is used for a variety of purposes within the NASARC modules, including file checking and verification in NASARC0, construction of the list of service areas to be examined within a portion of the orbit in the NASARC1 module, and assembling a list of compatible candidate service areas for group arc extension in the NASARC3 module.

Precise format information is contained in section 2.3.1.4 of this manual; for further discussion of the affiliated sets concept, the user is referred to the *NASARC (Version 2.0) Technical Manual* (see section 3.1.1.2.2).

An example Affiliated Sets file and a partial Service Area file are presented in figure 3.2-3.

3.2.5 Inputs to NASARC0 Program/Input Data File

As discussed in section 2.3.1.5, the Input Data file is produced by execution of the NASARC0 module. The Input Data file is largely composed of the user's responses to queries generated by the NASARC0 program. The input parameters to be supplied by the user are detailed in the subsequent sections; guidelines are also given for the selection of appropriate values.

FILE: ARC55AF CODES A

1	RE1	3
2	RE2	2

FILE: ARC55AF ARCS A

AGL	-27.00	62.00	
ARG	-83.00	-49.00	
BAH	-121.00	-33.00	
BEN	-48.00	52.00	
BFA	-48.00	46.00	
BLZ	-138.00	-40.00	
BRB	-110.00	-9.00	
B00	-87.00	-21.00	
CAN	-111.00	-95.00	
CHL	-95.00	-43.00	
CLM	-119.00	-31.00	2
CME	-36.00	61.00	
COG	-33.00	63.00	
CPV	-73.00	25.00	
CTI	-54.00	43.00	
CTR	-134.00	-35.00	
CUB	-123.00	-37.00	
DOM	-118.00	-23.00	
EQA	-127.00	-29.00	
E00	-31.00	25.00	
F00	-25.00	30.00	
GAB	-38.00	61.00	
GHA	-51.00	48.00	
GMB	-65.00	34.00	
GNB	-65.00	35.00	
GNE	-41.00	62.00	
GTM	-139.00	-42.00	
GUI	-60.00	37.00	
GUY	-109.00	-9.00	
G00	-36.00	34.00	
HND	-134.00	-39.00	
HTI	-121.00	-26.00	
ISL	-53.00	14.00	
JMC	-126.00	-29.00	
LBR	-59.00	40.00	
MEX	-135.00	-74.00	
MLI	-46.00	39.00	1
MLT	-26.00	55.00	
MRC	-43.00	32.00	
MTN	-52.00	32.00	
NCG	-134.00	-37.00	
NIG	-37.00	55.00	1
NMB	-25.00	61.00	
PNR	-129.00	-31.00	
POR	-41.00	26.00	
PRU	-120.00	-29.00	
SEN	-63.00	33.00	
SLV	-139.00	-39.00	
SRL	-62.00	38.00	
STP	-45.00	57.00	
TCD	-26.00	64.00	
TGO	-50.00	51.00	1
TRD	-112.00	-11.00	
USA	-113.00	-79.00	
VEN	-111.00	-22.00	2

Figure 3.2-3.—Example affiliated Set file/Partical Service Area file.

It is important for the user to keep in mind that the selection of certain input parameters (including threshold C/I, grouping criterion, and space-station antenna rolloff characteristics) has direct bearing on the number of compatible groups that may be generated within a portion of the orbital arc. The number of compatible groupings generated affects internal and external storage requirements utilized by the NASARC modules. If internal storage capacities are exceeded for any NASARC program module, an error message and abnormal termination of the current module will result. The user is therefore cautioned in the selection of unrealistic parameter values.

Following the discussion of required user inputs in the subsequent sections, the interactive prompts issued by the NASARC0 program and the correct formats for responses are presented in table 3.2-2. An example Input Data file is presented in figure 3.2-4.

3.2.5.1 Threshold Downlink Single-Entry Carrier-to-Interference Ratio

A threshold single-entry downlink C/I value is requested of the user. This value, expressed in dB, will be utilized in order to determine compatibility for each pair of service areas. The threshold C/I value is used in the calculation of the target C/I value that must be achieved or exceeded at the worst-case polygon point of the wanted service area, when the wanted and interfering satellites are separated by the orbital spacing given as the grouping criterion. Too small a threshold C/I value, in addition to perhaps being unrealistic, will result in the generation of an inordinately large number of groupings within the NASARC1 module.

3.2.5.2 Downlink Frequency

The user is requested by the NASARC0 module to supply a single downlink frequency (expressed in gigahertz). The frequency parameter has an important effect on antenna gain calculations and, therefore, on antenna discrimination calculations. The value of frequency supplied by the user is utilized directly or indirectly in the calculation of antenna on-axis gains, antenna half-power beamwidths, and coefficients for antenna discrimination equations; the frequency will affect antenna diameter-to-wavelength ratio, and thus may determine which set of equations are utilized to model the antenna fall-off characteristics for the earth station.

It is suggested that the user supply a frequency equal to the lower edge of the downlink bank for which he or she intends to apply NASARC; for exercises related to allotment planning of the Fixed Satellite Service, the selected frequency should lie in one of the following intervals:

$$4.5 \text{ GHz} \leq \text{FREQ} \leq 4.8 \text{ GHz}$$
$$10.7 \text{ GHz} \leq \text{FREQ} \leq 10.95 \text{ GHz}$$
$$11.2 \text{ GHz} \leq \text{FREQ} \leq 11.45 \text{ GHz}$$

3.2.5.3 Grouping Criterion

As has been stated, the NASARC software package enumerates, and operates on, groups of compatible service areas. Service areas are regarded as pairwise compatible if the satellite separation required to achieve the target C/I value falls at or below a given upper bound. This upper bound, the grouping criterion, is supplied by the user; it specifies, in degrees, the maximum separation between two satellites that must provide the required target C/I value if two service areas are to be regarded as compatible for grouping purposes. As an example, if a grouping compatibility criterion of 0.0 ° was specified by the user, only those service areas whose satellites were found to be colocatable would be regarded as compatible. If a grouping compatibility criterion of 1.0° was specified, those service areas whose satellites required 1° or less of orbital separation to achieve the target C/I value would be regarded as compatible.

If the grouping criterion is specified at a much higher value than 1.0°, flexibility of positioning within an allotted arc, which NASARC was designed to provide, may be lost. In addition, the maximum number of members in a compatible grouping that is allowable in NASARC (Version 2.0) may be exceeded, which will produce misleading results. Finally, program run time will be affected adversely by forcing the enumeration of many more groupings than would normally be expected; internal memory requirements may be exceeded as well.

3.2.5.4 Minimum Half-Power Beamwidth of Satellite Antenna

The minimum half-power beamwidth of the satellite antenna serves two purposes. As ellipses are read from the Ellipse file, those having major and/or minor axis beamwidths less than this minimum value are adjusted so that the minimum value is satisfied. In addition, the minimum half-power beamwidth is utilized within the fast roll-off antenna patterns—where the gain for any size beam falls off at the same rate as for the minimum size beam.

The minimum half-power beamwidth for the satellite antenna is interpreted as the entire half-power beamwidth, from edge-to-edge of coverage, rather than from center to edge. All calculations within the NASARC programs involving satellite half-power beamwidth interpret the beamwidth in this way.

It is suggested the user calculate a minimum beamwidth that is suitable for the chosen frequency and a reasonable physical size for the satellite antenna. As an example, a minimum beamwidth of 1.4° would correspond to satellite antenna diameter of 3.3 meters operating at a frequency of 4.50 gigahertz. Values of 0.8° and 1.6° have been suggested for allotment planning in the Fixed Satellite Service.

3.2.5.5 Earth Station Antenna Characteristics

In section 3.2.2.2.4, the specification of earth station antenna characteristics for individual service areas was discussed; the specific antenna characteristic models available in the NASARC (Version 2.0) software were discussed in sections 3.2.2.2.4.1 and 3.2.2.2.4.2.

The specific types of earth station antennas available to the user will not be re-examined here; rather, it is the purpose of this section to discuss the precise usage of the interactively specified earth station antenna characteristic.

It is possible, as the user saw in sections 2.3.1.2 and 3.2.2, to specify earth station antenna characteristics for each and every service area contained within the Service Area file, thus eliminating the need for default antenna characteristics for service areas that do not have individually specified characteristics. However, one further use is made of the interactively supplied set of earth station antenna characteristics that has not yet been described; this is the use of earth station antenna characteristics in calculation of the buffer length.

The buffer length is used as an optional factor in determining the allotted arc length to be given to a particular compatible group of service areas by the NASARC2 module (see eq. (3.2-13)). The user is referred to sections 3.1.2 and 3.3.4.2 of the *NASARC (Version 2.0) Technical Manual* for a more detailed explanation of the buffer length.

The application of the earth station antenna characteristics in the buffer length calculation will be described here.

The calculated buffer length is based on the sidelobe slope of the earth station antenna pattern envelope selected by the user. The user will recall from section 3.2.2.2.3 that two such patterns are available and are represented by the six-character codes ETA391 and ETAIMP. The code ETA391 refers to the earth station antenna pattern presented in Annex I of CCIR Report 391-4. ETAIMP also is presented in CCIR Report 391-4, having a 29-25 log (φ) sidelobe characteristic.

The equations for calculating the buffer length are as follows:

For $D/\lambda \geqq 100$ and antenna sidelobe envelope of 32-25 log φ:

$$B = 10^{[(C/I-6)-\mathrm{GMAX}+32]/25} \tag{3.2-3}$$

For $D/\lambda \geqq 100$ and antenna sidelobe envelope of 29-25 log φ:

$$B = 10^{[(C/I-6)-\mathrm{GMAX}+29]/25} \tag{3.2-4}$$

For $D/\lambda < 100$ and antenna sidelobe envelope of 32-25 log φ:

$$B = 10^{[(C/I-6)-\mathrm{GMAX}+52-10\log(D/\lambda)]/25} \tag{3.2-5}$$

For $D/\lambda < 100$ and antenna sidelobe envelope of 29-25 log φ:

$$B = 10^{[(C/I-6)-\mathrm{GMAX}+49-10\log(D/\lambda)]/25} \tag{3.2-6}$$

where

B	buffer length, deg
D	earth station antenna diameter, m
λ	wavelength corresponding to input frequency, m
C/I	threshold downlink carrier-to-interference ratio, dB
G_{MAX}	earth station on-axis gain, dB
6	single entry to aggregate C/I ratio, dB

Version 2.0 of NASARC utilizes a single-entry-to-aggregate C/I ratio of 6 dB which is used in conjunction with the user-supplied threshold single-entry C/I in the buffer equations. At the May 1987 IFRB Informational Meeting, an aggregate C/I value of 26 dB and a single-entry C/I value of 32 dB were recommended for planning purposes. Based on these values, a single-entry-to-aggregate C/I ratio of 6 dB was incorporated into the NASARC (Version 2.0) software. This value could be changed if desired, but such a change would require the recompilation of the NASARC0, NASARC1, and NASARC3 modules. (The program variable RATIO is set to 6.0.) This 6-dB difference between aggregate and single-entry C/I values should be sufficient to allow the desired aggregate C/I value to be met when the NASARC results are analyzed. When entering the threshold single-entry C/I value, it is recommended that a value be input which is 6 dB greater than the intended desired aggregate C/I value.

The default earth station antenna characteristics requested of the user by the NASARC0 program will always be utilized in the previous calculation of the default buffer length; they may also be used to supply characteristics for all service areas that do not have earth station antenna characteristics individually specified within the Service Area file. The prompts for input issued by the NASARC0 program will reflect the appropriate situation (see table 3.2-2).

3.2.5.6 Space Station Antenna Characteristics

Space station antenna characteristics are requested of the user by the NASARC0 program if there are service areas within the Service Area file that do not have such characteristics individually specified.

The space station antenna patterns available and their associated required parameters are as described in section 3.2.2.2.3 and its subsections. However, if the IWPIMP antenna is selected, its associated focal length-to-diameter ratio need not be specified. NASARC0 will assume a representative value of 2.0.

TABLE 3.2-2—INTERACTIVE PROMTS/USER RESPONSES FOR NASARC0 MODULE

"SPECIFY INPUTS AS REAL NUMBERS UNLESS PROMPTED OTHERWISE'

"INPUT REQUIRED SINGLE ENTRY *C/I*"
(Response: real number, dB)

"INPUT DOWNLINK FREQUENCY IN GHZ"
(Response: real number, range 4.5 to 4.8 GHz, 10.7 to 10.95 GHz, or 11.2 to 11.45 GHz)

"INPUT GROUPING CRITERION, DEGREES"
(Response: real number, range 0.0 to 1.0)

"INPUT MINIMUM BEAMWIDTH, DEGREES"
(Response: real number; 0.8, 1.6 have been suggested)

If all earth station pattern selections are furnished within Service Area file, the following message is displayed:

"THE EARTH STATION ANTENNA CODES FOR ALL SYSTEMS HAVE BEEN SPECIFIED IN THE SERVICE AREA FILE. PLEASE SELECT AN EARTH STATION ANTENNA TYPE FOR USE IN DETERMINING PDA ARC LENGTH.

AVAILABLE EARTH STATION ANTENNAS:

ETA391—E/S ANTENNA PATTERN PRESENTED IN CCIR REPORT 391-4 WITH 32-25 LOG (PHI) CHARACTERISTIC

ETAIMP—E/S ANTENNA PATTERN PRESENTED IN CCIR REPORT 391-4 WITH 29-25 LOG (PHI) CHARACTERISTIC.

ENTER 6—CHARACTER EARTH STATION ANTENNA CODE FROM MENU: YOUR CHOICES ARE: ETA391 ETAIMP"
(Response: Six characters, one of previous choices)

If earth station antenna patterns are not furnished for all service areas in Service Area file, this message is displayed:

"SELECT AN EARTH STATION ANTENNA CODE TO BE APPLIED TO ALL SERVICE AREAS WHICH HAVE NOT BEEN INDIVIDUALLY SPECIFIED IN THE SERVICE AREA FILE
AVAILABLE EARTH STATION ANTENNAS:

ETA391—E/S ANTENNA PATTERN PRESENTED IN CCIR REPORT 391-4 WITH 32-25 LOG (PHI) CHARACTERISTIC

ETAIMP—E/S ANTENNA PATTERN PRESENTED IN CCIR REPORT 391-4 WITH 29-25 LOG (PHI) CHARACTERISTIC

ENTER 6—CHARACTER EARTH STATION ANTENNA CODE FROM MENU: YOUR CHOICES ARE: ETA391 ETAIMP"
(Response: Six characters, one of previous choices)

If earth station antenna diameters are furnished for all service areas within Service Area file, the following message is displayed:

"THE EARTH STATION DIAMETERS FOR ALL SYSTEMS HAVE BEEN SPECIFIED IN THE SERVICE AREA FILE. PLEASE SELECT AN EARTH STATION DIAMETER FOR USE IN DETERMINING PDA ARC LENGTH.

ENTER EARTH STATION DIAMETER IN METERS

THE DEFAULT VALUE IS: 4.5

DO YOU WISH TO RETAIN THIS VALUE? (Y/N)"
(Response: One character, Y or N)

If the user's response was N, the following message is displayed:

"ENTER NEW VALUE"
(Response: real number, meters)

If earth station antenna diameters are not furnished for all service areas within the Service Area file, the following message is displayed:

"SELECT AN EARTH STATION DIAMETER TO BE APPLIED TO ALL SERVICE AREAS WHICH HAVE NOT BEEN INDIVIDUALLY SPECIFIED IN THE SERVICE AREA FILE.

TABLE 3.2-2.—Continued.

ENTER EARTH STATION DIAMETER IN METERS

THE DEFAULT VALUE IS: 4.5

DO YOU WISH TO RETAIN THIS VALUE? (Y/N)"
(Response: One character, Y or N)

If the user's response was N, the following message is displayed:

"ENTER NEW VALUE"
(Response: real number, meters)

If earth station antenna efficiencies have been specified for all service areas within the Service Area file, the following message is displayed:

"THE EARTH STATION EFFICIENCIES FOR ALL SYSTEMS HAVE BEEN SPECIFIED IN THE SERVICE AREA FILE. PLEASE SELECT AN EARTH STATION EFFICIENCY FOR USE IN DETERMINING PDA ARC LENGTH.

ENTER E/S EFFICIENCY AS DECIMAL PERCENT (0.55 = 55%)

THE DEFAULT VALUE IS: 0.65

DO YOU WISH TO RETAIN THIS VALUE? (Y/N)"
(Response: One character, Y or N)

If the user's response was N, the following message is displayed:

"ENTER NEW VALUE"
(Response: Real number, > 0.0 and ≥ to 1.0)

If earth station antenna efficiencies have not been specified for all service areas within the Service Area file, the following message is displayed:

"SELECT AN EARTH STATION EFFICIENCY TO BE APPLIED TO ALL SERVICE AREAS WHICH HAVE NOT BEEN INDIVIDUALLY SPECIFIED IN THE SERVICE AREA FILE.

ENTER E/S EFFICIENCY AS DECIMAL PERCENT (0.55 = 55%)

THE DEFAULT VALUE IS: 0.65

DO YOU WISH TO RETAIN THIS VALUE? (Y/N)"
(Response: One character, Y or N)

If the user's response was N, the following message is displayed:

"ENTER NEW VALUE"
(Response: Real number, > 0.0 and ≤ to 1.0)

If space station antenna patterns and parameters have been supplied for all service areas in Service Area file, the following message is displayed:

"THE SPACE STATION ANTENNA CODES AND REQUIRED PARAMETERS HAVE BEEN SPECIFIED FOR ALL SYSTEMS IN THE SERVICE AREA FILE."
(Response: No user response required.)

NOTE: Default space station antenna code, 'RARCST'
Default parameter value, 0.0
Default antenna efficiency, 0.55

If space station antenna patterns have not been supplied for all service areas in the Service Area file, the following message is displayed:

"SELECT A SPACE STATION ANTENNA CODE TO BE APPLIED TO ALL SERVICE AREAS WHICH HAVE NOT BEEN INDIVIDUALLY SPECIFIED IN THE SERVICE AREA FILE. AVAILABLE SPACE STATION ANTENNAS:

SCA558—SATELLITE ANTENNA PATTERN PRESENTED IN CCIR REPORT 558-3

TABLE 3.2-2.—Concluded.

RARCST—STANDARD ROLL-OFF SATELLITE ANTENNA PATTERN GIVEN IN THE RARC '83 FINAL ACTS

RARCFR—FAST ROLL-OFF SATELLITE ANTENNA PATTERN GIVEN IN THE RARC '83 FINAL ACTS

FASTRO—IMPROVED FAST ROLL-OFF SATELLITE ANTENNA PATTERN PRESENTED IN DOCUMENT #AH-178-796 OF THE IRAC.

ORBITO—SATELLITE ANTENNA PATTERN UTILIZED IN THE ORBIT-II SYNTHESIS PROGRAM BY KDD OF JAPAN

ORBITF—ORBIT-II SATELLITE ANTENNA PATTERN WITH Δ −10 dB FLOOR ADDED

WARC77—SATELLITE ANTENNA PATTERN GIVEN IN THE WARC77 FINAL ACTS

IWP4/1—FAST ROLL-OFF SATELLITE ANTENNA PRESENTED IN CCIR REPORT 558-3. RECOMMENDED BY IWP4/1 AT ITS JUNE 1986 MTG.

IWPIMP—FAST ROLL-OFF SATELLITE ANTENNA RECOMMENDED BY IWP4/1 AT ITS MAY 1987 MTG.

ENTER 6-CHARACTER SATELLITE ANTENNA CODE FROM MENU; YOUR CHOICES ARE: SCA588 RARCST RARCFR FASTRO ORBITO ORBITF WARC77 IWP4/1 IWPIMP"
(Response: Six-character, one of previous choices)

If user's response is SCA558 or IWP4/1, the following message is displayed:

"ENTER SIDELOBE LEVEL, DB

THE DEFAULT VALUE IS: 25.0

DO YOU WISH TO RETAIN THIS VALUE? (Y/N)"
(Response: One character, Y or N)

If the user's response was N, the following message is displayed:

"ENTER NEW VALUE"
(Response: Real number, typically 15.0 to 30.0 dB)

If user's antenna specification was ORBITO or ORBITF, the following message is displayed:

"ENTER ANTENNA DELAY CONSTANT, ALPHA

THE DEFAULT VALUE IS: 3.5

DO YOU WISH TO RETAIN THIS VALUE? (Y/N)"
(Response: One character, Y or N)

If the user's response was N, the following message is displayed:

"ENTER NEW VALUE"
(Response: Real number, typically 3.5 to 5.5)

NOTE: If user's antenna pattern response was "IWPIMP" the NASARCO program will default the required focal-length-to diameter ratio to 2.0.

"ENTER SPACE STATION ANTENNA EFFICIENCY AS DECIMAL PERCENT (0.55 = 55%)

THE DEFAULT VALUE IS: 0.55

DO YOU WISH TO RETAIN THIS VALUE? (Y/N)"
(Response: One character, Y or N)

If the user's response was N, the following message is displayed:

"ENTER NEW VALUE"
(Response: Real number, ≥ 0.0, ⩾ to 1.0).

```
FILE: INPUT    ARC55AF  B

ERROR FLAG                               =   N
DOWNLINK C/I (DB)                        =    32.000
DOWNLINK FREQUENCY (GHZ)                 =     4.500
MINIMUM ELLIPSE BEAMWIDTH (DEGS.)        =     1.600
EARTH STATION ANTENNA CODE               =   ETA391
E/S ANTENNA DIAMETER (METERS)            =     4.500
EARTH STATION ANTENNA EFFICIENCY         =     0.650
SPACE STATION ANTENNA CODE               =   RARCST
SPACE STATION ANTENNA PARAMETER          =     0.000
SPACE STATION ANTENNA EFFICIENCY         =     0.550
AFFILIATED SETS FLAG                     =   Y
INDIVIDUAL ANTENNA SPECS. FLAG           =   N
GROUPING CRITERION (DEGREES)             =     1.000
CONSTANT C1: C1*(N-1)*CRIT               =     1.000
CONSTANT C2: C2*BUFARC                   =     1.000
CONSTANT C3: C3*N                        =     0.000
CONSTANT C4: C4                          =     0.000
BUFFER ARC LENGTH (DEGREES)              =     3.996
```

Figure 3.2-4.—Example Input Data file.

3.2.6 Ellipse Data

As stated in section 2.3.1.6, the input Ellipse file for the NASARC modules is furnished with the NASARC (Version 2.0) software package. Each record contains a three-character service area code, the orbital longitude at which the ellipse covering the service area was calculated, the latitude and longitude of the beam aimpoint, the orientation angle of the ellipse, and the ellipse major and minor axis beamwidths; ellipses for 222 service areas are included and they encompass the visible arc for each. The ellipse data contained in the file included with the NASARC software package were computed utilizing a specific minimum ellipse calculation program (Akima, 1981). However, an alternative ellipse calculation procedure might also be utilized so long as the output of the ellipse calculation is in the correct format to be utilized by the NASARC modules (see table 2.3-5).

For any ellipse calculation procedure used to construct a master ellipse file for use by the NASARC modules, it is important that the ellipse calculations for a service area be performed utilizing the same set of service area polygon points that the user intends to use in the NASARC Point Sets file. This will ensure maximal accuracy and consistency of the NASARC program calculations.

Ellipse data for service areas must correspond to alphabetical ordering of service areas; within each block of ellipse data, longitudes for which the ellipses have been calculated must range from the westmost longitudinal limit of the service area's visible arc to the east most limit of that arc. Thus, in blocks of data for service areas whose arcs cross the 180° meridian, the record containing the ellipse calculated at 180° east longitude must be immediately followed by the record containing the ellipse parameters calculated at −179° east longitude. As may be inferred from the preceding, ellipse records should reflect ellipse parameters calculated at 1° increments for integral (whole degree) longitudes.

3.3 Using NASARC (Version 2.0) Software Package

3.3.1 Invoking NASARC Programs

To utilize NASARC (Version 2.0) for a planning exercise, the NASARC procedure described in section 2.2.3 must be invoked by the user. The procedure will first load and execute the NASARC0 modules. The NASARC0 module will verify input data files for accuracy and prompt the user interactively for further input. When the user's responses have been gathered, the Input Data file will be generated.

The NASARC1, NASARC2, and NASARC3 modules will be executed in sequence for as many segments to be examined as are specified within the Segments file. Therefore, if the user's system does not allow DO-loop constructs within user-created procedures, the NASARC1, NASARC2, and NASARC3 modules must be loaded and executed as many times as necessary by the user.

When all the segments specified have been examined, the NASARC3 module will produce the NASARC Report file.

3.3.2 Error Messages and Their Meanings

Table 3.3-1 contains a complete list of error messages generated by the NASARC0, NASARC1, NASARC2, and NASARC3 modules. Information is also included on subroutines that produce the messages and suggested sources of error. This information is intended to allow the user to quickly and easily identify causes of program errors. The error messages will be written to the logical unit defined for error messages—unit 19. The messages will also appear on the user's screen; FORTRAN logical unit 10 should be defined as the user's terminal. The user is advised to examine the Error Message file if the expected results are not achieved (see section 2.3.3.2). The efforts described will generally result in premature termination of the module in question, with the exception of those indicated in the table. Errors, which result in necessary program termination, trigger the setting of an error flag in the Input Data file so that subsequent program modules are not executed on invalid data. The occurrence of various error messages might be eliminated by modifying the value of a parameter and recompiling to achieve a successful program run if the user has sufficient memory. All parameter names, the programs and/or subprograms in which they occur, and their current values are listed in the appendix.

TABLE 3.3-1—ERROR MESSAGES AND THEIR MEANINGS

Message	Program/subprogram producing message	Potential source of error
"ERROR—THE CONSTANTS USED IN DETERMINING PDA LENGTH HAVE ALL BEEN SPECIFIED AS 0.0 OR LEFT BLANK. PLEASE CHECK THE FIRST TWO RECORDS OF THE POINT SETS FILE."	NASARC0	1. Self-explanatory. All constants cannot be set to 0.0 at same time.
"ERROR—THE SEGMENT FILE BOUNDARIES DO NOT PROVIDE CONTINUOUS PROGRESSION OF CUMULATIVE ORBITAL ARC. CHECK THE SEGMENT WITH BOUNDARIES XXX.XX, XXX.XX."	NASARC0	1. A record of Segments file does not adjoin any previous segment. Correct the record indicated.

TABLE 3.3-1—Continued.

Message	Program/subprogram producing message	Potential source of error
"ERROR—THE SERVICE ARC SPECIFIED FOR AAA EXCEEDS THE MAXIMUM POSSIBLE VISIBLE ARC FOR POSITIVE ELEVATIONS, OR THE WEST AND EAST BOUNDARIES FOR AAA MAY BE REVERSED. CHECK THE SERVICE AREA FILE."	NASARC0	1. Self-explanatory; correct the record indicated in the Service Area file.
"ERROR—MEMBERS OF THE AFFILIATED SET WITH CODE NUMBER N DO NOT INTERSECT A COMMON PORTION OF THE ORBITAL ARC. CHECK SERVICE AREA FILE FOR THE WEST AND EAST BOUNDARIES OF AFFILIATED SET MEMBERS WITH CODE NUMBER N."	NASARC0	1. Incorrect Service Area may have been indicated as member of set with code number N. 2. A service arc for member service area may have been incorrectly specified.
"ERROR—THE SPACE STATION ANTENNA CODE SPECIFIED IN THE SERVICE AREA FILE FOR AAA IS NOT ONE OF THE AVAILABLE CODES. PLEASE CONSULT THE NASARC MANUALS FOR AVAILABLE CODES, THEN MAKE THE APPROPRIATE CHANGES TO THE SERVICE AREA FILE."	NASARC0	1. Self-explanatory.
"ERROR—AN ILLEGAL ANTENNA DATA ENTRY HAS BEEN MADE IN THE SERVICE AREA FILE FOR SERVICE AREA AAA. PLEASE BE SURE THE VALUES FOR DIAMETER, SPACE STATION PARAMETER, AND THE EFFICIENCIES ARE ALL POSITIVE."	NASARC0	1. Self-explanatory.
"ERROR—THE EARTH TERMINAL ANTENNA CODE SPECIFIED IN THE SERVICE AREA FILE FOR AAA IS NOT ONE OF THE AVAILABLE CODES. PLEASE CONSULT THE NASARC MANUALS FOR APPROPRIATE CODES, THEN MAKE THE APPROPRIATE CHANGES TO THE SERVICE AREA FILE."	NASARC0	1. Self-explanatory.

TABLE 3.3-1—Continued.

Message	Program/subprogram producing message	Potential source of error
"ERROR—THE NUMBER OF MEMBERS IDENTIFIED IN THE AFFILIATED SETS FILE FOR AFFILIATED SET N DOES NOT AGREE WITH THE AFFILIATED SET FLAGS IN THE SERVICE AREA FILE."	NASARC0	1. Incorrect number of members in Affiliated Set file for set N. 2. Incorrect number of service areas have been identified as members of set N within the Service Area file
"ERROR—THE SPACE STATION ANTENNA PARAMETERS INDIVIDUALLY SPECIFIED IN THE SERVICE AREA FILE FOR MEMBERS FROM AFFILIATED SET AAA ARE NOT THE SAME. ALL MEMBERS OF THE SAME AFFILIATED MUST HAVE IDENTICAL SPACE STATION PARAMETERS. PLEASE CORRECT THE PROBLEM AND RERUN."	NASARC0	1. Self-explanatory. Check all Service Area file entries belonging to affiliated set AAA.
"ERROR—THE NUMBER OF AFFILIATED SETS SPECIFIED IN THE CODE FILE DOES NOT AGREE WITH THE AFFILIATED SETS FLAG IN THE SERVICE AREA FILE. PLEASE CORRECT THE PROBLEM AND RERUN."	NASARC0	1. Three are more/less unique affiliated sets identified in the Affiliated Sets file than are identified in the Service Area file.
"DATA ENTRY ERROR—PLEASE ENTER A POSITIVE REAL NUMBER."[a]	NASARC0	1. User has entered a reponse of incorrect type to interactive prompt by NASARC0.
"YOU HAVE SPECIFIED A FREQUENCY OUTSIDE OF THE BANDS ALLOCATED FOR ALLOTMENT PLANNING PURPOSES. PLEASE CHECK YOUR DESIRED VALUE AND RE-ENTER."[a]	NASARC0	1. User has specified a downlink frequency that is outside the range: (a) 4.5-4.8 GHz (b) 10.7-10.95 GHz (c) 11.2-11.45 GHz
"YOU HAVE NOT SELECTED A VALID EARTH ANTENNA; PLEASE SELECT AGAIN. YOUR CHOICES ARE—ETA391 ETAIMP."[a]	NASARC0	1. Self-explanatory.
"PLEASE ENTER YOUR PREFERENCE AS Y OR N."[a]	NASARC0	1. The user has supplied a response inconsistent with a required Y or N response.

[a]Does not terminate program execution.

TABLE 3.3-1—Continued.

Message	Program/subprogram producing message	Potential source of error
"DATA ENTRY ERROR—PLEASE ENTER A VALUE BETWEEN 0.0 AND 1.0."[a]	NASARC0	1. The user has responded incorrectly to prompt for antenna efficiency. Efficiencies are expressed as decimal percentages (e.g., 55% = 0.55).
"YOUR HAVE NOT SELECTED A VALID SATELLITE ANTENNA; PLEASE SELECT AGAIN. YOUR CHOICES ARE: SCA558 FARCST RARCFR RASTRO ORBIT0 ORBITF WARC77 IWP4/1 IWPIMP."[a]	NASARC0	1. Self-explanatory.
"DATA ENTRY ERROR—PLEASE ENTER A POSITIVE VALUE FOR THE SIDELOBE LEVEL (TYPICALLY IN THE RANGE 15.00 TO 35.00)."[a]	NASARC0	1. Self-explanatory.
"END OF FILE REACHED ON POINTS SETS FILE AFTER N FILES SKIPPED"	NASARC1/POSPAR	1. Empty Point Sets file—recheck file definition. 2. Missing file separator in Points Sets file. 3. Missing block of data in Point Sets file.
"ERROR READING POINT SETS FILE AFTER N FILES SKIPPED"	NASARC1/POSPAR	1. Point Sets file contains error in one of more records that causes error in FORTRAN READ.
"NO POINT SET FOUND FOR AAA"	NASARC1/RDPTST	1. Point Sets file does not contain point set for a service area contained in Service Area file. 2. Point set corresponding to service area has code that does not match service area code.
"ERROR READING POINT SET DATA WHILE LOOKING FOR KEY BBB: LAST KEY READ BEFORE ERROR OCCURRED: AAA"	NASARC1/RDPTST	1. Point Sets file contains error in one or more records that causes error in FORTRAN READ.
"WESTERN ARC LIMIT FOR AAA IS INCONSISTENT WITH ELLIPSE FILE."	NASARC1/CREATE	1. Ellipse file incorrectly constructed. 2. Service arc for service area AAA incorrectly specified.
"EASTERN ARC LIMIT FOR AAA IS INCONSISTENT WITH ELLIPSE FILE."	NASARC1/CREATE	1. Ellipse file incorrectly constructed. 2. Service arc for service area AAA incorrectly specified.

[a]Does not terminate program execution.

TABLE 3.3-1—Continued.

Message	Program/subprogram producing message	Potential source of error
"ERROR WHILE SEARCHING FOR ELLIPSE FOR AAA"	NASARC1/CICHK	1. Ellipse array incorrectly constructed; check Ellipse file.
"A GROUP EXCEEDS MAX NUMBER OF MEMBERS AND IS TRUNCATED. THE ARC LOCATION IS XXX.XX: CURRENT SEGMENT IS XXX.XX TO XXX.XX."[a]	NASARC1	1. A compatible group of service areas has more than MAXMEM members. Redistribute arc segments in Segments file.
"THE MAXIMUM NUMBER OF GROUPS HAS BEEN EXCEEDED WITHIN THE SEGMENT XXX.XX TO XXX.XX AT THE LOCATION XXX.XX. ADJUST SEGMENT LIMITS WITHIN THE SEGMENTS FILE."	NASARC1/ACCUM	1. The total number of compatible groups of service areas has exceeded MAXGRP. Redistribute arc segments in Segments file.
"ERROR: THERE ARE MORE GROUPS IN THE SUBLIST THAN THE ARRAYS CAN HOLD. INCREASE THE VALUE OF MAXSUB IN THE NASARC2 SOURCE CODE, RECOMPILE, AND RE-EXECUTE."	NASARC2/CRTGRP	1. There are too many groups that contain the critical service area. Increase MAXSUB or reduce list of compatible groupings by other means.
"ERROR: THERE ARE MORE GROUPS IN THE INPUT LIST THAN THE ARRAY CAN HOLD. INCREASE THE VALUE OF MAXRMN IN THE NASARC2 SOURCE CODE, RECOMPILE, AND RE-EXECUTE."	NASARC2/INRMN	1. There are too many groups in Unallotted Groups file that adjoin current segment. Adjust parameter or reduce list by other means.
"ERROR: THERE ARE MORE GROUPS IN THE INPUT LIST THAN THE ARRAYS CAN HOLD. INCREASE THE VALUE OF MAXGRP IN THE NASARC2 SOURCE CODE, RECOMPILE, AND RE-EXECUTE."	NASARC2/INGRPS	1. There are too many groups contained in the NASARC1 module output Groups file. Adjust parameter as suggested or reduce list by other means.
"END OF FILE REACHED ON POINT SETS FILE AFTER N FILES SKIPPED."	NASARC3/POSPAR	1. Empty Point Sets file—recheck file definition. 2. Missing file separator in Point Sets file. 3. Missing block of data in Point Sets file.
"ERROR READING POINT SETS FILE AFTER N FILES SKIPPED"	NASARC3/POSPAR	1. Point Sets file contains error in one or more records that causes error in FORTRAN READ.

[a]Does not terminate program execution.

TABLE 3.3-1—Concluded.

Message	Program/subprogram producing message	Potential source of error
"NO POINT SET FOUND FOR AAA"	NASARC/RDPTST	1. Point Sets file does not contain point set for a service area contained Service Area file. 2. Point set corresponding to service area has code that does not match service area code.
"ERROR READING POINT SET DATA WHILE LOOKING FOR KEY BBB: LAST KEY READ BEFORE ERROR OCCURRED: AAA"	NASARC3/RDPTST	1. Point Sets file contains error in one or more records that causes error FORTRAN READ.
"ERROR WHILE SEARCHING FOR ELLIPSE FOR AAA"	NASARC3/CICHK	1. Ellipse array incorrectly constructed; check Ellipse file.

3.4 Interface Considerations for NASARC and Synthesis Program ORBIT

The general approach proposed for allotment planning consists of two phases. The first phase is the use of NASARC to identify predetermined arc segments common to groups of service areas. Those service areas within a group and sharing a common predetermined arc segment would be able to position individual space stations at any one of a number of orbital positions within the arc segment. The second phase is the use of the synthesis program ORBIT to identify example scenarios of space station placements. Given *N* space stations to be placed in a predetermined arc of *X* degrees, runs of the synthesis program ORBIT would identify scenarios of acceptable space station placements within the NASARC generated predetermined arc segments subject to other constraints common to both NASARC and ORBIT: *C/I*, space and ground antenna characteristics, and other technical parameters (see *NASARC* (*Version* 2.0) *Technical Manual* for further details).

It can be seen that an interface between the NASARC program and the ORBIT program is required. Presently such an interface does not exist in a computerized mode, and the transfer of data between the programs must be performed manually. Therefore, the following instructions for going from a NASARC run to an ORBIT-II run have been included in the is manual. It is not the intent of this section to educate the user on how to run the ORBIT-II program; for that, the user is referred to the *ORBIT-II User's Manual*. It is the intention of this section to relate and interpret the inputs and outputs of the two programs—NASARC and ORBIT-II.

3.4.1 Use of ORBIT-II in Planning Stage

The primary purpose of the synthesis program ORBIT-II at the time of plan development is to identify example placements of space stations in the plan, thereby demonstrating that the allotment plan can "guarantee in practice for all countries equitable access to the geostationary orbit." If an individual ORBIT-II run is made on a single grouping, various example scenarios can be generated by varying the launch order to show the existence of multiple satellite arrangements within the grouping which can meet the interference criteria, thereby demonstrating flexibility of orbital position. ORBIT-II is also equipped to include the uplink interference contribution into its calculation. The individual ORBIT-II runs can also be used to demonstrate the flexibility NASARC provides for individual system parameter variations.

A secondary purpose that may be accomplished through use of the ORBIT-II program at the time of plan development is to perform a full aggregate interference analysis of the complete groupings and predetermined arcs that NASARC produces. This type of ORBIT-II run is referred to as an aggregate run. In these aggregate

runs, all service areas represented within the scenario are included, and the interference effects of neighboring groupings are accounted for.

An individual ORBIT-II run has a total satellite number equal to the grouping size. An aggregate ORBIT-II run has a total satellite number equal to the scenario size. Therefore, the individual ORBIT-II runs will have greatly reduced computational complexity, and run times to create example scenarios will be relatively short. The remainder of this section is devoted to discussing which ORBIT-II input values are common to NASARC and which are the result of a NASARC run, for both the individual and aggregate ORBIT-II runs used in the planning stage.

3.4.2 ORBIT-II Input Data Resulting from NASARC

There are basically three categories of input data that may be derived for ORBIT-II from a NASARC run. First, there are common input parameters: single-entry interference criterion, lower limit of 3-dB beamwidth, space station antenna characteristics, earth station sidelobe peak and slope, and service point location. (Note: The single-entry interence criterion is used in ORBIT-II primarily to determine the relative positioning of satellites and may, therefore, be specified at a higher value than in NASARC to help ORBIT-II achieve a solution.) Second, there are ORBIT-II input parameters that may be calculated from input parameters to NASARC. ORBIT-II requires the earth station transmit and receive antenna diameter to wavelength ratio (D/LAMBDA) for its operation. This can be easily calculated from the uplink/downlink frequencies, and the earth station antenna diameter input to NASARC. Also required by ORBIT-II are the earth station transmit and receive antenna gains which can be calculated from NASARC's earth station antenna diameter, uplink/downlink frequencies, and antenna efficiency. These common input parameters are used in the same way in both an individual and aggregate type of ORBIT-II run and are summarized in table 3.4-1.

TABLE 3.4-1—ORBIT-II INPUT DERIVED FROM SCENARIO INFORMATION

ORBIT-II	NASARC
Single-entry interference criterion	Common
Lower limit of 3-dB beamwidth	Must be divided by two for present version of ORBIT-II
Space station antenna characteristics	Common (to the extent available in ORBIT-II)
Earth station sidelobe peak/slope	Derived from the antenna code specified
Service point location	Common
D/LAMBDA (Tx and Rx)	Calculated from earth station antenna diameter and uplink/downlink frequencies
Earth station (Tx and Rx) antenna gain	Calculated from earth station antenna diameter, frequency, and antenna efficiency

The third category of input data derived for ORBIT-II from a NASARC run is that data obtained from the NASARC output. ORBIT-II requires the total satellite number, total available arc, and service arc. For an individual ORBIT-II run on a single grouping, the total satellite number equals the number of group members and the total available arc corresponds to the allotted arc. The service arc input parameter can be set to the original service arc, or the allotted arc, since the allotted arc is contained within the service arc and the satellite is already constrained to the allotted arc by the specified total available arc. For an aggregated ORBIT-II run of the groupings and predetermined arcs resulting from a NASARC run, the total satellite number corresponds to the total number of service areas represented in the scenario. The service arcs for the service areas should be defined

as the appropriate allotted arcs. The total available arc for an aggregate ORBIT-II run must completely encompass all groupings' allotted arcs and can be specified to be as large as the geostationary orbit itself, since the allotted arcs (input as service arcs) constrain the satellites to the proper region. (Note: the current version (Version 3.87) of ORBIT requires a small gap in the total available arc specification, such that the full 360° can not be specified.) Table 3.4-2 summarizes these input relationships.

TABLE 3.4-2—ORBIT-II INPUTS DERIVED FROM NASARC RESULTS

ORBIT-II input parameter	Individual grouping run	Aggregate scenario run
Total satellite number	Number of group members	Number of service areas represented in the scenario
Total available arc	Allotted arc	Geostationary orbit
Service arc	Allotted arc	Allotted arc

3.4.3 Other ORBIT-II Input Data

To run the ORBIT-II program, other input data relating to the uplink parameters and minimization software are required. In this section these parameters are discussed and possible defaults are proposed. As stated earlier, the primary purpose of the ORBIT-II program is to demonstrate the flexibility of orbital positions within the allotted arcs produced by NASARC. Based on the descriptions of an individual or aggregate run, ORBIT-II must be operated in the mode in which optimization is performed under constrained service arcs (allotted arcs). This is achieved by specifying FIX in the FIX/FREE input category for each satellite (service area) represented in the ORBIT-II run. Also, when it is desired that ORBIT-II analyze aggregate interference, the PLANNING-II option (rigid planning under aggregate interference) should be specified.

There are five global ORBIT-II input parameters that are not directly related to the NASARC methodology but pertain to the optimization procedures of the ORBIT-II program. They are the grouping unit, number of overlapping satellites among groups, internal launching order, total number of frequency slots, and number of maximum test slots. These input parameters do not greatly effect the result; they are primarily used to reduce computational time. For these reasons, they are not discussed further and the user is referred to the *ORBIT-II User's Manual* for details concerning what value to assign to them.

The remaining ORBIT-II input parameters, which must be determined independently of the NASARC run, that are required to initiate the program are satellite transmit gain, total interference, min/max HPA (earth station) power, min/max TWTA (satellite) power, and a test point for each service area. It is suggested that the satellite gain be specified greater than or equal to the gain produced by an antenna providing the minimum half-power beamwidth; ORBIT-II will default to those values obtained by the minimum area ellipse routine. The total interference is not part of the NASARC input (NASARC is based on single-entry interference) but must be selected such that it does not exceed the single-entry interference criterion used to determine the compatible groups of service areas. A good approximation for total interference could be

$$C/I\ TOTAL\ (\mathrm{dB}) = C/I\ S.E.\ (\mathrm{dB}) - 6\ (\mathrm{dB})$$

The power specifications for the earth station should be specified as some realistic value and should be the same for all satellites. For the satellite it is necessary to calculate the power for each service area separately in order to approximate the constant p.f.d. approach employed within the NASARC methodology. The final parameter, a test point for each service area, is an additional service point which must be located within the service area interior.

3.4.4 Automated Interface Requirements

Presently, creation of ORBIT-II input files based on NASARC results is done manually. It is foreseeable that a computer program could be produced that would read the appropriate input values for ORBIT-II from the NASARC Report file (parameters discussed in section 3.4.2). The program would be required to perform the necessary calculations shown in table 3.4-1. The user could be prompted for the other ORBIT-II input parameters given in section 3.4.3 with possible defaults included. The output of the program would be a file containing all the required input information pertaining to an individual grouping or aggregate scenario run in the correct format for submission to the ORBIT-II program.

REFERENCES

Akima, H.: A Method for Determining the Minimum Elliptical Beam of a Satellite Antenna. NTIA Report 81-88, National Telecommunications and Information Administration, Oct. 1981. (Avail. NTIS, PB82-153966).

The Orbit Spacing Minimizer (ORBIT-II) User's Manual. Kokusai Denshin Denwa Co., LTD. Apr. 1984.

APPENDIX—NASARC PROGRAM PARAMETERS

The NASARC program parameters described in the following table largely affect array dimensions within one or more NASARC modules. Thus, they will also affect the storage requirements of the modules in which they occur. The values listed in the table were carefully selected to provide the programs with maximum capability to accommodate a variety of scenarios, while still permitting each module to be loaded within the 6-megabyte memory limitation of the IFRB computer system.

The user is reminded that if a parameter value is changed within the NASARC source code, the appropriate module must be recompiled prior to use.

NASARC PROGRAM PARAMETERS

Name	Definition	Locations	Value[a]
MAXITU	Maximum number of service area records that may be contained in the Service Area file	NASARC0: MAIN NASARC1: MAIN CREATE NASARC3: MAIN REPORT	300
MAXCOD	Maximum number of service areas to be included in affiliated sets	NASARC0: MAIN	99
MAXSEG	Maximum number of segments to be examined, within the Segment file	NASARC0: MAIN NASARC1: MAIN NASARC2: INSEGS NASARC3: MAIN REPORT	

[a]Values are those that meet the 6-megabyte memory limitation of the IFRB computer.

Name	Definition	Locations	Value[a]
MAXTER	Maximum number of affiliated sets of service areas within Affiliated Sets file	NASARC0: MAIN NASARC1: MAIN NASARC3: MAIN REPORT	25
MAXMEM	Maximum number of service areas that may be included in a compatible group	NASARC0: MAIN NASARC1: MAIN NASARC2: INGRPS INALLT LSTALT CRTGRP UPDATE UNPACK GRPBUF XTRACT PULL INDEX2 NASARC3: MAIN REPORT UNPACK	15
MAXELL	Maximum number of ellipse records that may be contained in Ellipse file	NASARC1: MAIN CREATE	32,000
MAXGRP	Maximum number of compatible groups and group arcs that may be produced by NASARC1 within a single segment of the orbit	NASARC1: MAIN ACCUM OUTLST NASARC2: MAIN INGRPS JOINER CRTADM CRTGRP OUTRMN	63,000
MAXPT	Maximum number of polygon points for each service area	NASARC1: MAIN RDPTST NASARC3: MAIN RDPTST	10
MAXTEM	Maximum number of groups, group arcs in temporary list	NASARC1: MAIN ACCUM	10,000
NUMR	Number of groups, individual arc locations processed at one time, in creating temporary list of groups, group arcs	NASARC1: MAIN ACCUM	10,000

[a]Values are those that meet the 6-megabyte memory limitation of the IFRB computer.

Name	Definition	Locations	Value[a]
MSGELL	Maximum number of ellipe records to be utilized in single segment of the orbit	NASARC1: MAIN CREATE CICHK NASARC3: MAIN CICHK	16,000
MSGITU	Maximum number of service areas to be examined for compatibility within single segment of the orbit	NASARC1: MAIN RDPTST OUTLST NASARC2: MAIN INGRPS INALLT PARTIT CRTADM MISSP1 LSTALT CRTGRP P1CHK ITUARC GRPBUF NASARC3: MAIN RDPTST	100
MAXALT	Maximum number of allotted groups (over all segment of orbit)	NASARC2: MAIN INALLT CRTADM TEMPOR LSTALT SEGCHK PTACHK PUSH SHUFFL ARCCHK NASARC3: MAIN REPORT	150
MAXSUB	Maximum number of groups containing critical service area	NASARC2: MAIN GRTCRP XTEND	18,000
MAXRMN	Maximum number of unallotted groups that adjoin either edge of current segment of orbit	NASARC2: MAIN INRMN JOINER	10,000
MAXREC	Maximum number of records in NASARC2 Intermediate Selection file, Unallotted Groups file	NASARC2: MAIN INRMN OUTRMN	1,000,000
MAXPTA	Maximum number of potential temporary allotments within a group's group arc	NASARC2: TEMPOR	180
MAXD	Maximum number of groups in the critical groups sublist for which duplicates or subsets exist	NASARC2: XTEND	18,000
MAXF	Maximum number of aggregate arcs for subset arc extensions	NASARC2: COMBIN	100

[a]Values are those that meet the 6-megabyte memory limitation of the IFRB computer.

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16. Abstract

The information contained in the *NASARC* (*Version* 2.0) *Technical Manual* (NASA TM-100160) and the *NASARC* (*Version* 2.0) *User's Manual* (NASA TM-100161) relates to the state of Numerical Arc Segmentation Algorithm for a Radio Conference (NASARC) software development through October 16, 1987. The technical manual describes the NASARC concept and the algorithms which are used to implement the concept. The *User's Manual* provides information on computer system considerations, installation instructions, description of input files, and program operation instructions. Significant revisions have been incorporated in the Version 2.0 software over prior versions. These revisions have enhanced the modeling capabilities of the NASARC procedure while greatly reducing the computer run time and memory requirements. Array dimensions within the software have been structured to fit within the currently available 6-megabyte memory capacity of the International Frequency Registration Board (IFRB) computer facility. A piecewise approach to predetermined arc generation in NASARC (Version 2.0) allows worldwide scenarios to be accommodated within these memory constraints while at the same time effecting an overall reduction in computer run time.

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